Network Structure and Business Survival: The Case of U.S. Automobile Component Suppliers

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Abstract

We examine how three aspects of network structure affect supplier performance, focusing on relationship duration, supplier autonomy, and customer status. We examine their impact in different competitive contexts by considering differences in the modular and architectural technological characteristics of the components. Using data on all U.S. automotive carburetor and clutch manufacturers from 1918 to 1942, we find that suppliers of architectural goods (carburetors) benefit from long-term relationships, high status customers, and current autonomy. By contrast, only autonomy affects suppliers of modular goods (clutches). This comparison speaks to the contingent nature of the influence of network structure, with the benefits and constraints deriving largely from the nature of the inter-firm routines firms create to coordinate relationships. Relationships requiring extensive sets of inter-firm routines lead to greater benefits and constraints of network structure, while network structure has more restricted influence on relationships requiring less intensive inter-firm routines.

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ABSTRACT

We examine how three aspects of network structure affect supplier performance, focusing on relationship duration, supplier autonomy, and customer status. We examine their impact in different competitive contexts by considering differences in the modular and architectural technological characteristics of the components. Using data on all U.S. automotive carburetor and clutch manufacturers from 1918 to 1942, we find that suppliers of architectural goods (carburetors) benefit from long-term relationships, high status customers, and current autonomy. By contrast, only autonomy affects suppliers of modular goods (clutches). This comparison speaks to the contingent nature of the influence of network structure, with the benefits and constraints deriving largely from the nature of the inter-firm routines firms create to coordinate relationships. Relationships requiring extensive sets of inter-firm routines lead to greater benefits and constraints of network structure, while network structure has more restricted influence on relationships requiring less intensive inter-firm routines.

(Buyer-supplier relationships, status, structural autonomy, relationship duration)
NETWORK STRUCTURE AND BUSINESS PERFORMANCE: THE CASE OF U.S. AUTOMOBILE COMPONENT SUPPLIER SURVIVAL

Recent studies in organization theory and business strategy argue that the structure of a firm's network of inter-organizational relationships can both help and harm the firm's performance. Networks offer benefits through means such as providing access to information, creating shared understandings that facilitate decision-making, and sharing resources in order to gain scale and scope economies. At the same time, networks can create constraints such as making some firms dependent on others, diffusing proprietary information, and reducing independent adaptability. Despite our increasing understanding that inter-firm networks affect firm performance, research is just beginning to scratch the surface of what we mean by networks and how different aspects of network structure will influence firm performance in different competitive contexts (Podolny and Page 1998; Burt 2000).

This study examines the influence of network structure on the performance of supplier firms in vertical relationships with buyers. We argue that the structure of a supplier's network of customer relationships creates benefits and constraints that influence supplier performance. We address three aspects of the structure of a supplier's network of customer relationships: duration of relationships, autonomy within a network, and status of relationships. We further consider how network effects will differ for goods with architectural and modular technological properties.

Our empirical study examines the effects of network structure on the survival of 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. The results help demonstrate how different aspects of network structure affect business performance in different technological contexts.

THEORY AND HYPOTHESES

Prior studies suggest key aspects of network structure that will 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; Mitchell and Singh 1996). 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 network structure in influencing firm performance. Indeed, no study has modeled the joint effects on firm performance of all three aspects of network structure.

Buyer-supplier relationships offer an intriguing opportunity to study network structure because all three aspects of network structure influence firm performance in this setting. Buyer-supplier relationships tend to involve many firms of different size and status, through both direct and indirect relationships of varying length (Martin, Swaminathan and Mitchell 1998). Moreover, buyer-supplier relationships play key roles in industry evolution, by influencing the development and distribution of new goods and services (Clark and Fujimoto 1991).

The remainder of this section develops our arguments concerning how network structure influences supplier performance in the context of buyer-supplier relationships. We state the predictions concerning supplier performance in terms of business failure. Failure is an appropriate measure for the empirical context of our study, in which financial performance measures are not available. Moreover, business failure is a strong indicator of financial problems, particularly in commercial contexts in which business divestiture offers an alternative, perhaps successful, means of exiting an industry.

**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. Trust in a supplier
relationship includes both interpersonal trust between individuals who span the organizational
boundary and interorganizational trust. Long-term patterns of interaction between individual
boundary-spanners allow role definitions and organizational structures and routines to become
institutionalized. As new individuals enter the boundary-spanning role, they become socialized
into this institutionalized environment. After sufficient time has passed for the institutionalizing
process to take hold, trust between the organizations may then be more enduring than trust
between individual boundary-spanners who come and go. Zaheer, McEvily and Perrone (1998)
found that high levels of inter-organizational trust correlated with lower costs of negotiation and
with superior performance for the exchange partners. They speculate that this is due to
transaction value (Zajac and Olsen 1993), which is cooperation that goes beyond the efficiencies
of eased negotiation. Trust allows firms to engage in cooperative activities that would be difficult
to manage purely by contractual relationships. In his examination of relationships among firms in
the New York apparel industry, Uzzi (1996) found that relationships embedded in an ongoing
social structure exhibited a high-degree of trust between participants. Trust-enabled buyer-
supplier cooperation in the automobile industry and similar sectors includes shifting product
development activity to the supplier and the exchange of technical and marketing personnel
(Clark and Fujimoto 1991).

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 1991). 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. 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. By contrast, modular components are
more general goods that require little refinement to either component or end-product. 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. 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.

**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 network structure.
We begin with a general discussion of dependence. We then develop a specific form of the
structural autonomy concept, drawn from Burt's (1992) work, which views autonomy in terms of
constraint and oligopoly.

**Dependence and autonomy**

It is commonly recognized that suppliers that become dependent on their buyers often
face performance problems resulting from opportunistic behavior by partners or from lack of
access to necessary information. Williamson (1993) argues that firms in long-term relationships
can face hold-up problems in partner behavior if they do not have alternative partners. Singh and
Mitchell (1996) found that firms commonly faced adaptation difficulties in times of
environmental change if they became too reliant on 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. 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. The second aspect of network structure, then, is the degree of
autonomy that a supplier enjoys in its relationships with buyers, where autonomy is the converse of dependence.

Supplier autonomy is the degree to which a supplier can act independently of its buyers. Consistent with common usage, we will refer to dependence as the power of a buyer over its suppliers. As we discuss below, a buyer's power over a supplier incorporates both the potential for a buyer to act opportunistically with respect to a supplier and the potential that a buyer may lack the knowledge needed to coordinate inter-firm activities effectively. Emerson (1962) defines the power of firm A over firm B as the difference of A’s dependence on B and B’s dependence on A. While there are advantages to a supplier becoming tightly bound to an 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; Cusumano and Takeishi 1991). 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. Such negative influences of buyer power are compatible with the positive cooperative activities associated with tight linkages. Many relationships have both competitive and symbiotic elements (Pfeffer and Salancik 1978).

Because of the risks of dependence, firms often seek to minimize their dependence on outside organizations. The most effective strategy for dealing with dependence driven by reliance on a single market may be to alter the organization’s purposes and structure so that it no longer serves only a few markets (Pfeffer and Salancik 1978). A supplier can diversify its customer base either within its current markets or by seeking out entirely new markets. In early 2000, for instance, the Japanese auto supplier Unisia Jecs Corporation undertook the intra-market diversification strategy by seeking to reduce its sales to Nissan from 80 percent to about 55 percent over a six-year period, by increasing its sales to other auto manufacturers (AFX-Asia 2000). As an example of inter-market diversification, Pfeffer and Salancik (1978) document Israeli manufacturing companies that sought out new customers predominantly in markets into which they did not already sell heavily. The strategy of inter-market diversification reduces
dependence both on a given buyer and on a given market. But, inter-market diversification also reduces the extent to which the supplier firm can share activities within a market, diminishing the advantages that come with such relationships. Therefore, diversification of relationships within a market, which will require new relationship-specific investment and coordination but less market-specific investment, is a common way of attempting to reduce dependence.

**Structural autonomy**

Burt’s (1992) concept of structural autonomy provides an indicator of a supplier’s relative competitive position in a network, built upon formal measures of the alternatives available to each supplier. In the spirit of Burt’s (1992) formulation, we define the structural autonomy of an actor as a function of two components, constraint and oligopoly.

In simplified form, the autonomy measure \( A_i \) for any firm \( i \) is a multiplicative function such that: \( A_i = C_i^{-1} \times O_i^{-1} \).

Constraint \( (C_i) \) is a measure of how severely an actor’s network of relationships constrains its actions. Burt (1983) used the concept of constraint to account for the extent to which the absence of alternatives affects dependence. The more constrained one actor is, the more another actor's actions, or inactions, impose limits on its performance (Mizruchi 1992). Constraint is an aggregate measure of the investment that ego, the focal actor, has made in its relationship with alter, another actor, and the alternatives available to ego (Burt 1992). In the commercial setting, for instance, the investment a supplier has made in its relationship to a buyer is equal to the proportion of the supplier’s business that comes from that buyer. Buyer oligopoly \( (O_i) \) is the other component of structural autonomy. Oligopoly is a measure of the alternative partnership opportunities that are available to the focal actor outside its current network of exchange partners. In the buyer-supplier setting, the key question is how easily a supplier could find a buyer outside its current set of buyers. It follows that supplier autonomy is higher at lower levels of supplier constraint and buyer oligopoly.

Although a supplier may be dependent on its buyer’s business, if the buyer also becomes dependent on that supplier, the dependencies may balance each other. Following Emerson (1962), such balance creates a more even power relationship. Such bilateral dependence would exist if the buyer had no alternative sources for the components that the supplier provides or if complex routines had developed that spanned the boundaries of the two firms, making the assembler unable to easily replace the supplier (Baker 1990: 594-595; Singh and Mitchell 1996).
The critical consideration here is the relative autonomy of suppliers and buyers within their current relationships and the potential autonomy that arises from the ability to locate new partners outside the current network of relationships.

We extend Burt’s (1992) conceptual formulation of autonomy. Unlike the original one-sided view of autonomy, we view current and potential autonomy from the perspective of both buyers and suppliers. Therefore, the current autonomy of a supplier is the dependence of a supplier on its existing buyers relative to the dependence of its set of buyers on their suppliers. Similarly, the potential autonomy of a supplier is the opportunity available to a supplier to form ties to new buyers outside its existing set of buyers relative to the opportunities available to the supplier’s set of buyers to develop ties to new suppliers outside their current set of 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 is higher when it has many buyers available outside its current set of buyers and, on average, its current buyers have few alternatives to their existing set of 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 should they arise in a relationship.

**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 possible that current autonomy will have a greater influence on architectural suppliers, owing to the high need for relation-specific routines. Alternatively, current autonomy may provide benefits for all suppliers, by providing greater sales opportunities and helping firms resist the demands of a small number of customers.

**Supplier Status and Performance**

We now turn to status, which is the third aspect of network structure that we consider. Status, which is the degree to which other firms in an industry view a firm with deference, may provide economic benefits to a firm (Podolny 1993). An important source of status is a firm’s network of affiliations with prominent organizations that themselves possess legitimacy and high status (Podolny and Page 1998). 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 daycare centers with links to legitimate organizations such as churches were more likely to survive. Stuart, Hoang, and Hybels (1999) found that ties to prominent 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 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.

Affiliations with prominent partners transfer status to the focal firm by providing information that helps resolve doubts about its quality. Third parties often trust the ability of
prominent organizations to judge the quality of their affiliates (Stuart 1998). Because of this combination of the prominent organization’s incentives and perceived good judgment, affiliation with a prominent organization provides a strong signal to third parties about the focal firm’s quality.

In the context of a buyer-supplier network, 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 status effects, 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.

Second, increased status via the implicit endorsement of a prominent buyer 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 prominent 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 suppliers’ customers, the less likely the suppliers will fail.
The effect of status 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. 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 high-status customers.

**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 the structure of buyer-supplier networks that we expect to influence supplier survival. Figure 1 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, again 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.

********** Figure 1 about here **********
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 customer 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 Baily (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 network of ties between supplier firms and buyer firms for carburetors and clutches for each year.\footnote{This longitudinal network of ties is a set of rectangular matrices with unequal numbers of buyers and suppliers in each year, unlike the cross-sectional square input-output tables that Burt (1992) analyzed.}

Automotive Industries professes to list every model of automobile produced in the United States. This allows us to overcome two common challenges in network studies, defining the boundaries of the network 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-Year Almanac and 1996 Market Data Book (1996). The Statistics and Specifications issue of Automotive Industries also lists total automotive industry shipments for each year.

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 (Page, 1918; Dyke, 1923). Newcomb & Spurr (1989) note that "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. ⁵

Clutches, by contrast with carburetors, had become relatively standard even by the beginning of the study period. Page (1918: 635) notes that "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) note that "once established [by about 1919] the basic principles

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⁵ Fuel injection, which represents a new technological trajectory for fuel systems, did not come into extensive use until the mid-1970s, after our study period.
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 judgement of other customers, even high-status 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 (1991), 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 1975).

**Methods and dependent variable**

We define supplier failure as business dissolution, that is, cases in which supplier firms shut down the component business. We estimate the instantaneous rate of supplier dissolution, denoted by $r(t)$:

$$r(t) = \lim_{\Delta t \to 0} \left[ p_i(t, t + \Delta t)/\Delta t \right]$$

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 (Guo 1993; Barnett and Hansen 1996), 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:

$$r(t) = r^*(t) \exp(\alpha P_i + \beta S_{it})$$

where $r(t) ^*$ is the baseline hazard rate, $P_i$ is a matrix of variables measuring environmental conditions (time-varying, but invariant across suppliers), $S_{it}$ 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. Given the small number of divestitures, we treated divestiture as a censoring event rather than as a competing risk. Following Petersen (1991), we treated dissolutions as having occurred midway though the year to reduce potential estimation bias.

We estimated separate failure rate models for the two populations of carburetor and clutch suppliers. 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. Figures 2 and 3 describe trends in density and exits of carburetor and clutch suppliers respectively.

Independent Variables

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

**Table 1 about here**

Focal variables

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

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

---

3 There were 11 carburetor supplier divestitures and 6 clutch supplier divestitures between 1918 and 1970. Conceptually, divestitures tend to result from different influences that dissolutions; sometimes resulting from business failure and sometimes from business success.
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 its longest-standing partner, which provide a sales base with which to protect it from 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.

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. Thus, taking alternative approaches to conceptualizing status, such as focusing on mean status of a supplier's customers, would inappropriately reduce the impact of having a high status customer. We will use sensitivity analysis to assess this assumption.

In addition, we do not expect that having low status customers will be damaging for supplier firms. In some social situations, a prominent organization would place its own status at risk if it affiliated a low-quality partner, so that prominent organizations have strong incentives to be cautious in their selection of partners (Podolny 1994; Podolny and Phillips 1996; Stuart, et
al. 1999). However, this negative dynamic is unlikely to affect the buyer in the buyer-supplier relationship. Having a high-status customer provides legitimacy to the supplier for the reasons discussed above. The fact that the supplier also sells its goods to lower-status customers does not detract from this endorsement. We test this assumption in sensitivity analyses.

For possible measures of customer status, we considered two approaches, with the first based on status categories and the second approach based on sales levels. The first approach relies on a generally accepted recognition of three status categories within the automobile industry. 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 so-called major independents (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 later years. 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. For example, in the mid-1930s, Graham hovered between being a major independent and falling into the ranks of minor independents. Our results were robust to moving these three assemblers between the higher and lower of their possible status categories.

For the second approach to determining customer status, we measured assembler status according to its share of total automotive industry sales in each year. The contemporary literature clearly correlated firm sales with firm reputation. Also, firms with high sales were more prominently covered in the trade and general press. We found that the two measures of customer status were highly correlated with each other (0.78 for carburetor suppliers and 0.82 for clutch suppliers).

For our analysis, we chose to use the categorization approach to measuring customer status. The status categories exhibit less year-to-year variation than the measure based on sales. Theoretically, we prefer the categorization measure, because status effects will be less affected by yearly changes in the sales of a supplier’s largest customer than by the knowledge that a supplier sold components to a major assembler or only to minor independents. Empirically, our results are robust using either measure.
We set the status of a supplier equal to the status of the highest-status assembler to which it sold components. This provides a maximum status scale, with values of 1 (sold only to minor independents), 2 (sold to at least one of the major independents but no major assemblers), or 3 (sold to at least one of the major assemblers). We assume that in vertical relationships, association with a high status customer creates a protective umbrella under which suppliers can nurture other relationships with a variety of customers. As we discussed above, we also defined status in terms of mean customer status and minimum customer status for sensitivity analysis. These alternative operationalizations of status imply different aggregation rules employed to create an overall status measure from affiliations with individual customers. Status measured as the mean value of all customers implies that they contribute equally to a supplier’s reputation. Status measured as the minimum value of all customers implies that a supplier’s reputation might be adversely affected through its affiliation with a low status customer.

For our measures of current and potential autonomy, we draw on the work of Burt (1980; 1982; 1983; 1992). As we discussed earlier, a supplier’s current autonomy encompasses both how constrained a supplier is by its relationships with its buyers and how constrained its buyers are by their relationships to their existing suppliers. A buyer constrains a supplier more if its purchases represent a greater proportion of the supplier’s total sales (Burt 1980). Similarly a supplier constrains a buyer more if it purchases a large proportion of its inputs from that supplier.

We had information about the existence of ties between individual suppliers and assemblers in each year, rather than on each supplier’s sales to each assembler. We used these data to construct measures of current and potential autonomy of suppliers relative to their buyers. We measured the current autonomy of a supplier as the ratio of the number of assemblers to which the supplier sold to the average 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 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 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.

**Control variables**

We defined control variables for aggregate customer production, supplier size, supplier age, competitor density, national auto production, and national disposable income. 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 are not available. However, it is reasonable to assume that suppliers that sold to large assemblers such as General Motors and Ford would tend to have greater aggregate sales than suppliers that sold components to much smaller firms such as Dort and Geronimo.

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 classified in the category AAA or greater ($500,000 or greater capitalization), and a value of zero otherwise. The results are robust to using an ordinal measure of size based on the rank measures in the *Thomas Register*.

The variables for customer sales 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.

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 whose life histories were left-censored.

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 counter argument (Hannan, 1998), on the assumption that firms with stronger capabilities tend to become older and larger than firms with weak capabilities.

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. 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.

RESULTS

Table 2 reports the results of the analysis of carburetor and clutch supplier failure. 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 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 \( (1-e^{-2.78}) \). 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 structural 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.

Model 1d in Table 2 supports hypothesis 3a, which predicted that failure rates would decline with customer status. We find that maximum status has a significant effect for carburetor manufacturers. Therefore, supplying the top tier (status equal to 3, e.g., Ford) is associated with an exit rate only 8.5% \( (e^{-1.01\times(3-1)}) \) that of firms supplying only the minor independents (status equal to 1, e.g., Dort). 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 correlation of relationship duration with the autonomy and status variables is only moderate, with \( r < .30 \) in Table 1). 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 network structure 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). 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 network structure 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.

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 2d of Table 2 shows that customer status does not affect the failure rates of modular suppliers. 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.

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 relationship 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 any arithmetic relationship between density and autonomy might be influencing the results.

**DISCUSSION**

Podolny (1999) describes two views of networks, as pipes and prisms. The concept of autonomy assumes that a network is a pipe or conduit through which resources flow. Firms create an advantageous position for themselves by creating networks that are high in structural autonomy. The alternative view of networks as prisms is captured by the status order among firms in a market. Third parties ascribe higher status to firms that are linked to other high-status firms. We find that both aspects of network structure affect supplier survival contingent upon the type of component manufactured. Network structure both provides access to resources and shapes how a firm is viewed in an industry, most strikingly in the case of architectural suppliers.
Our results show that network structure has different influences on the failure rates of suppliers of modular and architectural components. For suppliers of modular components, only autonomy has major influences, 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 network structure (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 of network structure, while relationships that require less intensive inter-firm routines are less influenced by network structure. Nonetheless, even producers of seemingly-standard products benefit from having current autonomy from their customers.

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). 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.

The paper explores a tension between the interorganizational relationship and network views of the firms involved in vertical relationships. The interorganizational relationship view draws attention to the benefits of strong exclusive ties with a few firms (Levithal and Fichman 1988; Baker, et al. 1998). Such tight coupling results when firms are strongly reliant on each
other, often having many interdependent business routines. Tight coupling between suppliers and buyers permits the development of strong firm-specific interorganizational experience that may confer competitive advantages on suppliers (Lamming 1990). But such tightly-coupled relationships also create constraints on adaptation by buyers and suppliers. Network views of the firm draw attention to the potential disadvantages of such arrangements because they often correspond to low structural autonomy of the focal supplier firm. Low autonomy often has adverse effects on firm performance because the focal supplier firm derives fewer control and information benefits from its network and because the dominant partner can extract rents from its partner (Caves and Uekusa 1976; Pfeffer and Salancik 1978; Burt 1992). The network view, therefore, suggests that suppliers that have higher structural autonomy are better able to withstand partner demands and are better able to scan the industry for sources of resources.
<table>
<thead>
<tr>
<th>Table 1. Descriptive statistics and product-moment correlations (1918-1942 period)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carburetor suppliers (225 cases)</strong></td>
</tr>
<tr>
<td>Supplier age: 0-5 years</td>
</tr>
<tr>
<td>Supplier age: 6-10 years</td>
</tr>
<tr>
<td>Supplier age: 11-15 years</td>
</tr>
<tr>
<td>Supplier age: 16+ years</td>
</tr>
<tr>
<td>Competitor density</td>
</tr>
<tr>
<td>Left-censored</td>
</tr>
<tr>
<td>Large supplier</td>
</tr>
<tr>
<td>Aggregate cust. pdn. (mln units)</td>
</tr>
<tr>
<td>National auto production (mln units)</td>
</tr>
<tr>
<td>National disposable income ($ mln)</td>
</tr>
<tr>
<td>Max. duration of cust. relationship</td>
</tr>
<tr>
<td>Current autonomy</td>
</tr>
<tr>
<td>Potential autonomy</td>
</tr>
<tr>
<td>Prop. of vertically integrated cust.</td>
</tr>
<tr>
<td>Customer status (max.)</td>
</tr>
</tbody>
</table>

| **Clutch suppliers (130 cases)** | mean | s.d. | min. | max | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Supplier age: 0-5 years | 0.29 | 0.46 | 0.00 | 1.00 | 1.00 |
| Supplier age: 6-10 years | 0.20 | 0.40 | 0.00 | 1.00 | -0.30 | 1.00 |
| Supplier age: 11-15 years | 0.24 | 0.43 | 0.00 | 1.00 | -0.35 | -0.29 | 1.00 |
| Supplier age: 16+ years | 0.27 | 0.45 | 0.00 | 1.00 | -0.37 | -0.31 | -0.37 | 1.00 |
| Competitor density | 11.15 | 4.73 | 3.00 | 18.00 | -0.13 | -0.10 | 0.26 | -0.04 | 1.00 |
| Left-censored | 0.22 | 0.42 | 0.00 | 1.00 | -0.26 | 0.08 | 0.37 | -0.18 | 0.36 | 1.00 |
| Large supplier | 0.42 | 0.50 | 0.00 | 1.00 | 0.06 | 0.16 | -0.09 | -0.11 | -0.31 | 0.23 | 1.00 |
| Aggregate cust. pdn. (mln units) | 2.59 | 1.06 | 0.94 | 4.46 | 0.09 | -0.21 | -0.12 | 0.21 | -0.24 | -0.23 | 0.20 | 0.20 | 1.00 |
| National auto production (mln units) | 2.59 | 1.06 | 0.94 | 4.46 | 0.09 | -0.21 | -0.12 | 0.21 | -0.24 | -0.23 | 0.20 | 0.20 | 1.00 |
| National disposable income ($ mln) | 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 |
| Max. duration of cust. relationship | 1.72 | 2.18 | 0.00 | 10.00 | -0.21 | 0.08 | 0.00 | 0.13 | -0.33 | -0.33 | -0.02 | 0.67 | 0.41 | 0.27 | 1.00 |
| Current autonomy | 5.36 | 10.42 | 0.50 | 60.02 | -0.13 | 0.28 | 0.03 | -0.16 | -0.03 | 0.23 | -0.14 | 0.42 | -0.07 | -0.08 | 0.38 | 1.00 |
| Potential autonomy | 6.63 | 2.51 | 0.53 | 13.00 | -0.07 | -0.12 | 0.17 | 0.01 | 0.07 | 0.24 | -0.14 | -0.61 | -0.36 | -0.20 | -0.57 | -0.42 | 1.00 |
| Prop. of vertically integrated cust. | 0.13 | 0.29 | 0.00 | 1.00 | 0.23 | -0.09 | -0.13 | 0.02 | 0.03 | 0.15 | 0.11 | 0.16 | 0.15 | -0.05 | -0.08 | -0.09 | 1.00 |
| Customer status (max.) | 1.49 | 0.76 | 1.00 | 3.00 | 0.23 | 0.17 | -0.07 | -0.31 | -0.30 | -0.24 | 0.17 | 0.76 | 0.15 | 0.07 | 0.51 | 0.52 | -0.56 | 0.31 | 1.00 |
Table 2. Piece-wise exponential model of network structure influences on supplier failure rates
(negative coefficient = lower failure rate)

<table>
<thead>
<tr>
<th></th>
<th>Carburetors</th>
<th>Clutches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1a 1918-1942</td>
<td>1b 1918-1942</td>
</tr>
<tr>
<td>Supplier age: 0-5 years</td>
<td>-2.575</td>
<td>-1.195</td>
</tr>
<tr>
<td>(0.31)</td>
<td>(0.65)</td>
<td>(0.95)</td>
</tr>
<tr>
<td>Supplier age: 6-10 years</td>
<td>-2.871</td>
<td>-0.502</td>
</tr>
<tr>
<td>(0.25)</td>
<td>(0.85)</td>
<td>(0.72)</td>
</tr>
<tr>
<td>Supplier age: 11-15 years</td>
<td>-4.430*</td>
<td>-1.653</td>
</tr>
<tr>
<td>(0.09)</td>
<td>(0.58)</td>
<td>(0.90)</td>
</tr>
<tr>
<td>Supplier age: 16+ years</td>
<td>-4.461*</td>
<td>-1.973</td>
</tr>
<tr>
<td>(0.09)</td>
<td>(0.47)</td>
<td>(0.68)</td>
</tr>
<tr>
<td>Left-censored</td>
<td>0.802</td>
<td>0.820</td>
</tr>
<tr>
<td>(0.12)</td>
<td>(0.15)</td>
<td>(0.16)</td>
</tr>
<tr>
<td>Large supplier (supplier size)</td>
<td>-0.449</td>
<td>-0.296</td>
</tr>
<tr>
<td>(0.43)</td>
<td>(0.62)</td>
<td>(0.49)</td>
</tr>
<tr>
<td>Aggregate customer production</td>
<td>-1.089*</td>
<td>-0.915</td>
</tr>
<tr>
<td>(0.07)</td>
<td>(0.11)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>Competitor density</td>
<td>-0.001</td>
<td>0.017</td>
</tr>
<tr>
<td>(0.99)</td>
<td>(0.82)</td>
<td>(0.40)</td>
</tr>
<tr>
<td>National auto production</td>
<td>0.353</td>
<td>0.286</td>
</tr>
<tr>
<td>(0.25)</td>
<td>(0.43)</td>
<td>(0.98)</td>
</tr>
<tr>
<td>National disposable income</td>
<td>0.009</td>
<td>-0.009</td>
</tr>
<tr>
<td>(0.82)</td>
<td>(0.83)</td>
<td>(0.81)</td>
</tr>
<tr>
<td>H1a, H1b: Max. duration of cust. relationship</td>
<td>-0.278***</td>
<td>-0.121*</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.09)</td>
<td>(0.22)</td>
</tr>
<tr>
<td>H2a: Current autonomy</td>
<td>-1.487***</td>
<td>-1.572***</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>H2a, H2b: Potential autonomy</td>
<td>-0.157</td>
<td>-0.103</td>
</tr>
<tr>
<td>(0.15)</td>
<td>(0.26)</td>
<td>(0.26)</td>
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<tr>
<td>Prop. of vertically integrated cust.</td>
<td>1.701*</td>
<td>2.286**</td>
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<td>(0.08)</td>
<td>(0.04)</td>
<td>(0.04)</td>
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<tr>
<td>H3a, H3b: Customer status (max.)</td>
<td>-1.233***</td>
<td>-1.231***</td>
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<tr>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.47)</td>
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<tr>
<td>Observations</td>
<td>225</td>
<td>225</td>
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<tr>
<td>Dissolutions</td>
<td>24</td>
<td>24</td>
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<tr>
<td>Log-likelihood</td>
<td>-28.5</td>
<td>-22.5</td>
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<tr>
<td>Log-likelihood ratio (df)</td>
<td>11.9 (1)***</td>
<td>20.9 (3)***</td>
</tr>
</tbody>
</table>

p values in parentheses (one-tailed tests for hypotheses; two-tailed tests for control variables)

*** p<.01, ** p<.05, * p<.10
Impact of Buyer-Supplier Network Structure 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)
Figure 2: Clutch firms by year
Figure 3: Carburetor firms by year
REFERENCES


