Network Characteristics and Organizational Survival: The Case of U.S. Automobile Component Suppliers

ANAND SWAMINATHAN
Graduate School of Management
University of California at Davis
One Shields Avenue
Davis, CA 95616-8609
Phone: (530) 752-9916; Fax: (530) 752-2924; E-mail: aswaminathan@ucdavis.edu

GLENN HOETKER
University of Michigan Business School
Ann Arbor MI 48109-1234
Phone: (734) 647-9596; Fax: (734) 936-8716; E-mail: ghoetker@umich.edu

WILL MITCHELL
University of Michigan Business School
Ann Arbor MI 48109-1234
Phone: (734) 764-1230; Fax: (734) 936-8716; E-mail: wmitchel@umich.edu

January 5, 2000 (version: Status_01_2000.doc)
ABSTRACT

We examine the effects of dyadic and network characteristics on supplier survival in the U.S. automobile industry. Using life-history data on all carburetor and clutch manufacturers from 1918 to 1972, we find that suppliers that have longer-term dyadic relationships with buyers and networks that are high in structural autonomy and status experience lower dissolution rates. Loosely-coupled networks featuring high structural autonomy enhance supplier survival particularly under adverse environmental conditions.
A common theme in research on interorganizational relationships is that long-term linkages provide several types of benefits to the firms involved. In the context of vertical relationships, such as those between buyers and suppliers, enduring relationships allow firms to develop trust (Cusumano, 1985; Heide and Miner, 1992; Zaheer, McEvily and Perrone, 1998). Trust between organizations can serve as the basis for exchanging goods and services that are difficult to price or contract (Gulati, 1995; Uzzi, 1996) and facilitate a variety of cooperative activities, such as product design and marketing (Hayes and Wheelwright, 1984; Womack, Jones and Roos, 1990; Clark and Fujimoto, 1991). More generally, as these interactions continue over time, the firms develop relationship-specific capital and skills (Levinthal and Fichman, 1988; Asanuma, 1989; Martin, 1996). An implication of this line of research is that long term interorganizational relationships often improve the performance of individual firms.

In addition to the influences of dyadic relationships, firm performance is also affected by the structure of the overall network of relationships in which a focal firm is embedded (Burt, 1992; Podolny and Page, 1998). The network view emphasizes that, while decisions to form, continue or terminate a relationship are often viewed on a dyadic level, this series of decisions forms an overall network, which has performance implications of its own. We examine the performance consequences of two aspects of the overall network of a focal firm – its structural autonomy and its status. Both high structural autonomy and status are expected to be beneficial for the focal firm. We will focus on the structural autonomy and status of suppliers, both because of intrinsic interest and because of their key role in tying industries together.

We examine the effects of link longevity, autonomy, status, and environmental shocks on supplier survival in the U.S. automobile industry. We develop hypotheses that relate the survival of manufacturers of two automotive components, carburetors and clutches, to the duration of the
suppliers' relationships with buyers and to the suppliers' autonomy and status. We test our hypotheses using data on the life histories of the population of first-tier carburetor and clutch manufacturers from 1918 to 1972, including the suppliers' relationships with the population of automobile assemblers over the corresponding period.

THEORY AND HYPOTHESES

Long-term Buyer-Supplier Relationships and Supplier Performance

Strong 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), and apparel manufacturing (Uzzi, 1997). Long-term interfirm supply relationships provide an alternative to the simple make-or-buy choice in which transaction-specific assets are employed internally and general assets are governed through short-term contracts (Williamson, 1975). Even for components that require transaction-specific investment, 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 (Monteverde and Teece, 1982; Helper, 1987; Lyons, Krachenberg and Henke, 1990; Masten, Meehan and Snyder, 1991). The benefits arise because long-term relationships lead to the development of trust and relationship-specific routines.
Trust in a supplier relationship includes both interpersonal trust between individuals who span the organizational boundary and interorganizational trust (Zaheer, McEvily and Perrone, 1998). 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 are socialized into this institutionalized society. 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 two benefits of high levels of inter-organizational trust. First, trust was associated with lower costs of negotiation. Second, beyond lowering negotiation costs, trust had a further, direct correlation with superior performance for the exchange partners. They speculate that this is due to “transaction value” (Zajac and Olsen, 1993), cooperation that goes beyond the efficiencies of eased negotiation.

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. By lowering transactional difficulties, this trust allows for the transfer of more fine-grained and tacit information, which increased the firms’ responsiveness to their environment. The trust also allowed firms to react to changing circumstances by developing joint problem-solving arrangements. As a result, firms tied to partners by embedded, as opposed to arms-length, relationships increased their probability of survival. If a firm became over-embedded, however, the lack of arms-length relationships would isolate it from the market’s imperatives and increase its likelihood of failure.

Trust allows firms to engage in cooperative activities that would be difficult to manage purely by contractual relationships (Cusumano, 1985). In a study of 136 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. Trust-enabled buyer-supplier cooperation includes shifting product development activity to the supplier and the exchange of technical and marketing personnel (Hayes and Wheelwright, 1984; Womack, Jones and Roos, 1990; Clark and Fujimoto, 1991).

In addition to the potential for creating trust, the act of interacting over a long period of time generates relation-specific skills. Each firm develops internal routines that are especially suited for interacting with the specific partner (Levinthal and Fichman, 1988; Asanuma, 1989; Martin, 1996). Firms also develop beneficial routines that span the two organizations (Nelson and Winter, 1982; Mitchell and Singh, 1996). Examples of such routines include just-in-time delivery systems, which require learning and investment on the part of both buyer and supplier (Clark and Fujimoto, 1991). Relationship-specific skills are also important in developing a fine-tuned understanding of their partner’s capabilities (Fichman and Levinthal, 1991).

Because of the advantages of trust and relationship-specific skills, long-term relationships should 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. Interfirm human asset cospecialization was positively correlated with both quality and new model cycle time, while site specialization was positively associated with lower inventory costs. Thus, a tightly integrated production network appears likely to outperform a loosely integrated production network characterized by low levels of interfirm specialization.

The benefits derived from long-term relationships often generate a sustainable competitive advantage for suppliers, since creating an efficient set of buyer-supplier relationships
tends to be a slow difficult process (Eccles, 1981; Heide and John, 1990). Therefore, we expect supplier firms that have a long-term relationship with at least one buyer will enjoy enhanced performance and survival prospects.

**Hypothesis 1:** The longer the duration of the longest relationship between a supplier firm and its assembler buyers, the lower the rate of dissolution of the supplier firm

**Supplier Autonomy and Performance**

Supplier autonomy is the degree to which a supplier can act independently of the power of its buyers. 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 assembler, dependence is likely to give the assembler significant power over the supplier, because most of the supplier’s efforts are involved in its relationship with the assembler. The supplier is dependent for the bulk of its sales on that assembler. Therefore, the assembler 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 (Caves and Uekusa, 1976; Baker, 1990; Cusumano and Takeishi, 1991). This behavior is compatible with the cooperative activities associated with tight-linkages, as many relationships have both competitive and symbiotic elements (Pfeffer and Salancik, 1978).

Because of these risks, 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 is 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. Pfeffer and Salancik (1978) document the latter strategy among Israeli manufacturing companies, which sought out new
customers predominantly in markets into which they did not already sell heavily. Diversification reduces dependence on a given buyer. But, diversification also reduces how tightly-coupled the firm can be with any given customer, diminishing the advantages that come with such tight coupling.

Even within a tightly coupled relationship, however, the supplier is not necessarily in a weak power position vis-à-vis the buyer. Although a tightly-coupled supplier is more dependent on its buyer’s business, if the buyer also becomes dependent on that supplier, the dependencies may balance each other out. Following Emerson (1962), balance creates a more even power relationship. 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). Thus, characteristics of the buyer and the supplier, their dyadic relationship, and the set of relationships throughout the entire network influence the distribution of power in each buyer-supplier relationship. Burt’s (1992) concept of structural autonomy is an overall indicator of a supplier’s relative competitive position in a network, built upon formal measures of the alternatives available to each party in each of a focal firm’s transactions. In Burt’s (1992) formulation, the structural autonomy of an actor is a function of two elements, constraint and opportunity.

Constraint 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 is able to impose limits on its ability to realize profits (Mizruchi, 1992). Constraint is an aggregate measure of the investment an actor has made in its relationship with a buyer and the alternatives
available to the supplier (Burt, 1992). In the commercial setting, an important measure of the investment a supplier has made in its relationship to a buyer is the proportion of the supplier’s business that comes from that buyer. Constraint is lowest when a supplier has relationships with many buyers and many other potential buyers. Constraint is highest when a supplier is exclusively committed to a single buyer and has no other potential buyers. In the extreme case of constraint, a supplier’s entire sales might be to a single buyer. Such a captive supplier has invested all its attention into that one buyer, making it highly constrained. However, autonomy considers not only the division of a supplier’s current investment of attention but also the availability of other potential buyers. Because it is possible for a supplier to form a relationship with a new buyer, the presence of potential buyers will reduce a supplier’s constraint. Thus, a supplier that sells to a single buyer in a market that is rich with potential buyers is less constrained than a captive supplier in a market with few alternative buyers.

The other component of structural autonomy is opportunity, a measure of the alternative partnership opportunities that are available to the focal actor’s exchange partners. In the buyer-supplier setting, how easily could a supplier’s buyers replace it? Having many current suppliers makes any individual supplier more dispensable to a buyer, all else being equal, thus improving the buyer’s bargaining position. Baker, Faulkner, and Fisher (1998) found that clients that spread their business across a greater number of advertising agencies were more likely to dissolve any one of these ties. The presence of a large number of potential suppliers also provides a buyer with alternatives.

Combining constraint and opportunity into structural autonomy provides a rigorous restatement and combination of Emerson’s (1962) and Pfeffer and Salancik’s (1978) logic. A supplier has the greatest autonomy when it has many current buyers, each highly dependent on it,
and many potential buyers. A supplier has the lowest autonomy when it has only one buyer, that buyer has many alternative suppliers, and there are no other potential buyers. The degree to which a buyer gains power over a tightly-bound supplier depends critically on the degree to which the buyer is tightly-bound to the supplier. Even in a monopsony situation, the degree of the buyer’s dependence on the supplier bounds the buyer’s ability to extract rents from the supplier.

We predict that higher autonomy will improve a supplier’s probability of survival. Higher autonomy captures two effects. 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, a high autonomy supplier should be able to negotiate greater benefits from its current buyers. Any given buyer is less likely to terminate purchases from the supplier. In addition, the supplier is less affected if a buyer does exit the relationship.

**Hypothesis 2:** The higher the structural autonomy of a supplier, the lower the rate of dissolution of the supplier firm.

**Supplier Status and Performance**

Status, the degree to which a firm is viewed as an important firm in an industry, may provide economic benefits to a firm (DiMaggio and Powell, 1983; Podolny, 1993). An important source of status is a firm’s network of affiliations. If a firm is affiliated with organizations that possess legitimacy or status, the firm may derive legitimacy or status from that affiliation (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.
firm. Because of this, firms may actively seek out high-status partners. For example, Han (1994) argued that firms seek out the services of high-status auditors because of the impact of this affiliation 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 the market value of the firm upon going public. Furthermore, 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 (Podolny and Phillips, 1996) find that the higher the status of a bank’s affiliates, the greater the bank’s growth in status.

Affiliations provide legitimacy by providing information, which helps resolve doubts about the quality of a firm. In some situations, a prominent organization would place its own status at risk if it affiliated a low-quality partner. Therefore, prominent organizations have a strong incentive to be extremely cautious in their selection of partners (Podolny, 1994; Podolny and Phillips, 1996; Stuart, Hoang and Hybels, 1999). In addition, third parties also often trust the ability of prominent organizations to judge the quality of their partners (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 firm’s quality.

In the context of a buyer-supplier network, this legitimacy provides at least two benefits. First, it provides 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 buyer firms to imitate the behavior of competitors further accentuates status effects (Haveman, 1993; Mezias and Lant, 1994; Miner and Haunschild, 1995). Such status effects are especially likely in highly uncertain environments (Spender, 1989). In such environments, firms are especially likely to imitate the supplier selection strategies of successful high-status buyers (DiMaggio and Powell, 1983).

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 SmithDoerr, 1996). Baker, Faulkner, and Fisher (1998) found that advertising agencies with high 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.

Both of these advantages of status require that the signal generated by the affiliation be disseminated among potential buyers, investors, and lenders. The actions of prominent buyers are more likely to be noticed by industry participants, the business press and analysts. 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).
For all these reasons, we hypothesize that selling to a high-status customer will improve a supplier’s probability of survival. We phrase our hypothesis in terms of a supplier’s highest status buyer. While affiliation with a lower status partner can be damaging to a firm (Podolny, 1994), this dynamic is unlikely to affect the supplier 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 should not detract from this endorsement.

**Hypothesis 3:** The higher the status of a supplier’s highest status customer, the lower the likelihood of dissolution of the supplier.

**Loosely-coupled Networks and Supplier Performance**

As described above, most research on buyer-supplier networks has emphasized the existence of positive interdependence between buyer and supplier firms. This is not surprising because positive interdependence tends to occur in communities where organizations possess complementary sets of resources, a common feature of buyer-supplier networks. Research by Womack, Jones, and Roos (1990), Clark and Fujimoto (1991), and Cusumano and Takeishi (1991) on the automobile industry describes mutually beneficial buyer-supplier management practices such as just-in-time deliveries, extensive exchange of information and personnel, and cooperation in product development.

Positive interdependence in organizational communities often leads to the emergence of collective strategies, especially under conditions of resource scarcity (Laumann, Galaskiewicz and Marsden, 1978: 461-462). Strategies are collective when the interests of other firms in the community are taken into account as part of each firm’s decisions. Collective strategies may arise through conscious planning and coordination by a central firm (Laumann, Galaskiewicz
and Marsden, 1978) or emerge through repetitive patterns of interorganizational activity (Dollinger, 1990: 269).

From the organizational community perspective, the existence of a collective strategy means that the actions of any single firm are constrained by the network structure made up of all links within the network. Assemblers vary in the degree to which they create networks that are tightly coupled. A general trend toward supplier rationalization, especially among U.S. assemblers, has greatly increased the strength of ties between buyers and suppliers as many suppliers have virtually become captive to their buyers. Tight coupling between suppliers and buyers allow for the development of strong firm-specific interorganizational experience that may confer competitive advantages on suppliers (1990), but also creates constraints on adaptation. Following Simon (1962) and Weick (1979: 185-187), Aldrich and Whetten (1981:388) argue that organizations embedded in tightly-coupled networks find it difficult to adapt to environmental changes affecting any single member of the network (see also Aldrich, 1979:325-327). The deleterious impact of external shocks diffuses rapidly through tightly coupled networks where individual firms are constrained in attempts at local adaptation. The key actor in tightly coupled vertical groups of firms in the automobile industry is the assembler and supplier performance is highly susceptible to performance swings at the assembler level. Adverse environmental conditions such as industry downturns are more likely to force suppliers out of the market if they are tightly coupled to buyer firms. Conversely, suppliers with high structural autonomy, embedded in loosely coupled networks, have an additional survival advantage over suppliers with low structural autonomy when faced with adverse environmental conditions.

**Hypothesis 4:** Under adverse environmental conditions suppliers with higher autonomy will experience lower dissolution rates when compared to suppliers with lower autonomy.
Buyer-Supplier Relationships In The Automotive Industry

The automotive sector is especially suited to studying the hypotheses developed above. Automotive assemblers and their suppliers are structured as a network of vertically related communities (Fombrun, 1988). During our study period, overall production of automobiles increased dramatically, but the number of assemblers and first-tier suppliers declined precipitously (Carroll and Teo, 1996). In 1918, manufacturers built 943,436 automobiles in the United States. In 1972, they produced over 8.5 million. Over the same period, there were dramatic changes in the populations of buyers and suppliers. There were 71 assemblers in 1918 (Seltzer, 1928:65). The number of assemblers grew to a 1921 peak of 88 firms before falling by 50% within a five year period, to only 44 firms in 1926 (Seltzer, 1928:65). The number of auto assemblers then fell to four by 1972. Over the same period, the number of firms supplying components directly to the automobile manufactures changed dramatically. Overall, there were 764 component manufacturers in 1914. This number increased to 2,123 in 1919, and fell to 936 by 1939 (Katz, 1977:270). Changes in the assembler population, as well as the relationship between the assembler and supplier population influenced both the high overall mortality of suppliers and the survival of individual suppliers. The effects of these changes illustrate the role of supplier autonomy and buyer status.

The level of supplier autonomy changed drastically during the period. Early in the industry’s history, suppliers held the upper hand. Prior to 1909, auto assemblers relied on suppliers who had experience in the manufacture of carriages and bicycles and provided much of the automobile design expertise. A measure of the importance of suppliers is that Ford depended almost entirely on independent suppliers before 1914 (Helper, 1991). There were many assemblers, with frequent entry and exit resulting in the continued presence of small,
inexperienced assemblers. In some cases, the suppliers also provided funding for assemblers (Kennedy, 1941:62). With a wide range of available buyers and possessing the critical resources of design expertise and financial capital, suppliers possessed high autonomy.

By 1920, however, changes began to occur which dramatically curtailed the autonomy of suppliers. Over the decade of the 1920s, major assemblers developed much of the technical expertise that had previously resided with suppliers (Hochfelder and Helper, 1996). This reduced assembler dependence on suppliers and allowed leading assemblers, that now held much of the technical expertise, to shift among suppliers and cause the dissolution of suppliers that lost business. Also during the 1920s, product and process innovation became progressively less important in the auto assembly sector, with greater emphasis being placed on costs (Langlois and Robertson, 1989). As costs became a greater issue, it became more important to use specialized technology for parts production. This trend had two results. First, assemblers that were financially and managerial capable of doing so vertically integrated into many of the functions that suppliers had previously carried out (Seltzer, 1928; Hochfelder and Helper, 1996). Nonetheless, in order to maintain flexibility in the face of demand changes, near-total integration was rare (Katz, 1977:266), leaving a substantial continuing role for suppliers. Second, though, the larger assemblers were also able to force their suppliers to make investments in specialized equipment and techniques. Suppliers that did not make such investments became higher cost suppliers (Helper, 1991), lost the business of the large assemblers, and risked going out of business.

These trends reduced the autonomy of suppliers. The drastic reduction in the number of assemblers during the 1920s reduced the number of potential buyers, even though total production was increasing. Suppliers that made extensive relationship-specific investments
became almost entirely dependent on those few relationships. Suppliers that did not make these investments became dependent on the custom of the small assemblers for their survival. With parts production activity being absorbed by the major assemblers, it became harder for suppliers to achieve a minimum efficient scale of operation (Hochfelder and Helper, 1996), increasing their dependence on each buyer.

Predictably, the balance of power shifted dramatically from the suppliers to the assemblers as the number of assemblers declined and their technical sophistication increased. Major assemblers had a high rate of return, while many suppliers had low profitability (Helper, 1991). The difference was partially due to the ability of major assemblers to demand that suppliers provide detailed cost of manufacturing information. As a result, the major assemblers were able to expropriate many of the benefits of cost reductions. Furthermore, the assemblers were able to insist that their suppliers share their technical developments with competitors that also served the assembler (Helper, 1991; Hochfelder and Helper, 1996).

Dramatic changes in the mix of assembler size that occurred between 1914 and 1972 also influenced supplier autonomy. Initially, there was at least a moderate degree of assembler variety. By 1916, Ford and General Motors were already the largest assemblers, but seven other firms, including Dodge and Packard, were recognized as middle-tier independents, making profits of about one-quarter General Motors’ profits (Kennedy, 1941:90). In 1919, Ford, GM and the seven middle-tier independents produced approximately 1,500,000 cars, about seventy-five percent of total production in the United States. Ford and GM still dominated, making 750,000 and 391,000 cars respectively, but the middle-tier independents were still substantial contributors, ranging form Dodge’s 124,000 production to Packard’s 12,397 (Kennedy, 1941:105). By 1923, the top thirteen companies produced ninety-five percent of total U.S.
production (Kennedy, 1941:159). Fifty-seven companies vied for the remaining five percent (Seltzer, 1928:65). This degree of concentration continued throughout the 1920s but then became somewhat more concentrated during the Great Depression. By 1938, the Big Three of Ford, GM, and Chrysler, which had acquired Dodge, led the industry. These three firms produced almost ninety percent of U.S. production (United States Federal Trade Commission, 1939:27). The middle-tier independents had been winnowed to five (Kennedy, 1941:307), which had about ten percent of total production. The lowest-tier assemblers produced only two percent of total U.S. production (United States Federal Trade Commission, 1939:27).

After the war, there was a temporary surge of success for the remaining independents, due partially to difficult labor negotiations at the Big Three and partially to pent-up demand from the war years (Katz, 1977:421). Six middle-tier independents, including Studebaker and Willys, increased their share of the market to fifteen percent by 1949, while several other small lower-tier companies, such as Crosley, continued to operate. The 1950s, though, saw the number of independents reduced to two firms, American Motors and Studebaker-Packard, through exit and merger. Studebaker-Packard then failed in 1963, leaving American as the only independent operating in 1972 (Katz, 1977:422).

In summary, the assembler population was a relatively undifferentiated pool of firms early in the history of the auto industry. Over the 1920s, the industry moved to having an upper-tier of firms, a smaller middle-tier that was within an order of magnitude of the upper-tier firms, and a lower-tier that became progressively smaller and weaker. With the exception of the immediate post-War period, the general pattern was the continuing withering away of the lower-tier firms and an increasing distance between the upper-tier and middle-tier assemblers. This decline in the number of potential buyers reduced supplier autonomy significantly.
The changed mix of assembler size also increased the importance for suppliers of selling components to large, high-status buyers. Early in the industry’s history, there were many assemblers that could provide the economic benefits and status advantages of a large buyer. Even in the 1920s, a supplier could gain substantial sales and establish legitimacy through supplying a firm such as Studebaker, even if the supplier was unable to sell to Ford, Chrysler, or GM. By the 1930s, this was increasingly less viable. There were fewer major independents, each of which fell farther and farther short of the Big Three. The lower tier provided very little demand or status. As the smaller firms exited and were not replaced by new entrants, it became necessary to be able to supply at least the middle-tier companies. Then, by the post-War period, even the middle-tier of assemblers did not provide the opportunity for a reasonable level of aggregate sales. In order to establish scale efficiencies and status, it was almost a requirement that a supplier supply at least one of the Big Three buyers.

These changes in the assembler population had predictable effects on the mortality of suppliers. With their autonomy reduced and fewer opportunities to establish legitimacy, mortality among suppliers was high. For example, in 1918, there were 18 carburetor suppliers. In 1931, there were only 8. In 1971, there were only 2 independent carburetor suppliers.

Two examples illustrate the importance of these changes. Rayfield was an early entrant in the carburetor field. In 1918, Rayfield supplied twenty-two auto assemblers, often supplying multiple models to individual buyers. Of those twenty-two buyers, none was a Big Three firm and only one, REO, was a middle-tier firm. By 1924, Rayfield was down to nine buyers. Many of its 1918 buyers had failed and Rayfield lacked the status of ties with a leading buyer to gain more substantial buyers. In 1925, Rayfield was down to five buyers. Moreover, REO had switched to Schebler as a carburetor supplier, leaving Rayfield with only lower-tier buyers as
customers. In 1926, Rayfield had only one buyer, McFarlan. When McFarlan switched to Schebler as a supplier, imitating the behavior of the more prominent manufacturer REO, Rayfield shut down.

Tillotson, another carburetor supplier, was somewhat more successful than Rayfield but also eventually failed. Tillotson also supplied primarily lower-tier companies, with one middle-tier buyer, Willys. Despite having no upper-tier buyers, Tillotson was able to survive until World War Two, but lacked the resources and status to gain additional middle-tier buyers, much less gain one of the Big Three as a buyer. Willys did not return to production of passenger automobiles after the War, leaving Tillotson totally dependent on the minor third-tier assembler, Crosley. With severely limited status and autonomy, Tillotson ceased being a carburetor producer in 1951, one year before Crosley itself failed.

DATA AND METHODS

Data

We studied the survival of first-tier U.S. suppliers of carburetors and clutches in the automotive industry. We chose these components because they represent important inputs into the automobile production process, there is substantial diversity of firms within these populations of component manufacturers, and data was 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. *Automotive Industries* identifies the first-tier suppliers of many components, 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. Using these data, we constructed the entire network of buyer-supplier relationships 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 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 first-tier suppliers for these components. We can also gather a complete inventory of the buyer-supplier relationships between the firms.

We gathered information on the performance and life history of individual suppliers from 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* (Crane Communications, 1996). The *Statistics and Specifications* issue of *Automotive Industries* also lists total automotive industry shipments for each year.

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 relationship in the auto industries from works including Fombrun (1988), Womack, Jones, and Roos (1990), Clark and Fujimoto (1991), Cusumano and Takeishi (1991) Helper (1991), and Hochfeld and Helper (1996).
Methods

We estimate the instantaneous rate of supplier dissolution, denoted by \( r(t) \):

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

where \( p_i \) is the probability that a supplier fails between two discrete time points and \( t \) measures firm age. We used a piece-wise 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 recommended in the presence of left-censoring (Guo, 1993), which is a feature 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:

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

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-changing 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. 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 log-normal specifications.

Our data are annual, so we update all time-changing covariates each year. Each annual spell was treated as censored on the right, except those that ended with the dissolution of the supplier. Given the small number of acquisitions, we chose not to estimate a competing risks hazard model. Instead, we treated acquisition as a censoring event. Following Petersen (1991), we treated exits as having occurred midway though the year to reduce potential estimation bias.
We estimated failure rate models for the pooled population of carburetor and clutch suppliers. In our analysis, however, we interact the clutch supplier dummy variable with autonomy and status to see if there are any differences across the two subpopulations. In the years between 1918 and 1972, there were 302 firm-year observations involving 37 separate carburetor suppliers. Of these, 24 suppliers exited through dissolution and 11 exited through acquisition. There were 178 firm-year observations involving 32 separate clutch suppliers between 1918 and 1972. There were 24 dissolutions and 6 acquisitions of clutch manufacturers. These counts do not include assemblers that vertically integrated into production of both components. We took these assemblers into account in our calculations of structural autonomy, as described below, but did not include them in our estimation because the forces driving their involvement in component production differed from those of the independent suppliers. Figures 1 and 2 describe trends in density and dissolutions of carburetor and clutch suppliers respectively.

[Insert figures 1 and 2 about here]

**Variables**

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. Rezeroing the count captures the effect of the decay of inter-organizational 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.
We set the status of a supplier equal to the status of the highest status assembler to which it sold. The contemporary literature clearly indicates that there were three distinct groups of assemblers by 1918, the major assemblers (Ford, General Motors and, following the acquisition of Dodge, Chrysler), the so-called “major independents” (e.g. Hudson, Packard), and minor independents (all others, e.g., Dort). We assigned each assembler to a category 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 listed above. The categorization of assemblers was stable, but not unchanging, 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 categories.

We draw on the work of Burt (1980; 1982; 1983; 1992) for our measures of structural autonomy. Autonomy encompasses both how constrained a supplier is by its relationships with its customers and the opportunities buyers have to use suppliers other than the focal supplier (Burt, 1992, chapter 2). A customer constrains a supplier more as its purchases represent a greater proportion of the supplier’s total sales (Burt, 1980). Since we did not have information on each supplier’s sales to each assembler, we used the number of assemblers to which the supplier sold as our measure of constraint. The greater the number of assemblers to which a supplier sold, the less constrained it was.

The other component of structural autonomy is opportunity, a measure of the alternative partnership opportunities that are available to the focal actor’s exchange partners (Burt, 1992). In the buyer-supplier setting, how easily could a supplier’s buyers replace it? Having many
current suppliers makes any individual supplier more dispensable to a buyer, all else being equal, thus improving the buyer’s bargaining position. Therefore, we include the average number of suppliers the focal supplier’s customers have in our calculation of autonomy. High values indicate high average buyer opportunity, which contributes to low supplier autonomy.

We base our measure of structural autonomy on Burt (1992), where the autonomy of firm i, $A_i$, is defined as

$$A_i = \alpha (O_i)^{\beta_o} C_i^{\beta_c}$$

where $C_i$ is a measure of supplier $i$’s constraint and $O_i$ is a measure of the opportunity supplier $i$’s customers have to use suppliers other than the focal supplier. Using our earlier measures, we multiply our constraint measure, the number of assemblers to which a supplier sold, by our opportunity measure, the average number of suppliers the focal supplier’s customers had. To generate the appropriate effect, we invert the opportunity measure before multiplication. Thus, a large number of customers and a low average number of suppliers for those customers both contribute to high autonomy.

An assembler can also 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 in the measure of autonomy. High values indicate greater buyer opportunity and thus lower supplier autonomy. We kept the proportion of customers that are vertically integrated as a separate variable, which we expect to have a positive effect on the dissolution rate of suppliers.

Our measure of adverse environmental conditions is based on trends in overall domestic automotive sales. We measured the proportion of recent years for which there was a year-on-
year decline in total sales. We report results based on a three year window, but our results are robust to windows of varying lengths.

We do not know how many clutches or carburetors each supplier sold to each assembler in a given year. However, it is reasonable to assume that, on average, suppliers that sold to both General Motors and Ford would have greater aggregate sales than suppliers that sold to Dort and Geronimo. To control for this, we include the aggregate sales of all of a supplier’s customers in a given year. Although the benefits to the supplier of assembler scale and status correlate, we can disentangle the two effects empirically by controlling for supplier size. The scale benefits of selling components to a large buyer arise only if the supplier actually achieves larger size itself. The status benefits, however, arise whether or not the supplier achieves greater size. We expect that hypothesis three will hold controlling for supplier size. We take our measure of supplier size from the *Thomas Register of American Manufacturers*. Suppliers in our sample range from size E (credit rating of $5,000-$9,999) to AAAA (greater than $1,000,000). The variable, large supplier, takes a value of 1 if the supplier is classified in the category AAA or greater ($500,000 or greater), and a value of zero otherwise. We measured firm age from its birth. When that information was not available, generally for smaller suppliers, we generated a random date of birth between 1907, the earliest known birth of a supplier in our data, and 1917, the year prior to our observation period. We included a dummy variable indicating firms for which this had been done to all estimations. Tables 1 and 2 provide descriptive statistics for the variables used in this study.

[Insert tables 1 and 2 about here]
Results

The baseline model (1) in table 3 includes only the firm age segments, density, supplier size, aggregate sales of the supplier’s customers, and an indicator of left censoring. All models include the four age periods. The piecewise model with four age periods is a statistically significant improvement over an unreported model holding the rate constant. The positive sign on the coefficient for left-censored firms in model one indicates that these firms, which we believe to have been primarily small firms, exited at a faster rate. Greater aggregate sales of a supplier’s customers lower the hazard of exit. The coefficient for supplier size is nonsignificantly negative. The base hazard rates for clutches and carburetors do not differ significantly.

[Insert table 3 about here]

Model two confirms our first hypothesis, 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 is reduced by a factor of .808 ($e^{-21.21}$). This means that slightly over three additional years reduces the rate of exit by half. The effect remains statistically significant, although slightly smaller in magnitude, in subsequent models.

Model three strongly supports our second hypothesis, that failure rates would decline with supplier autonomy. Each increase of one in the structural autonomy score reduces the exit rate to approximately one-quarter its previous rate. This result persists in later models, with the exception of the final model, in which the sign of the coefficient remains negative. Exit rates are nonsignificantly higher for suppliers who have a greater proportion of customers that are vertically integrated.
The next two models test our third hypothesis, that higher status lowers the rates of exit. In model four, the coefficient on status is far from significant, although it has the expected sign. Model five adds an interaction term, which allows us to estimate separate effects of status for carburetor and clutch suppliers. We now find that status has a significant effect for carburetor manufacturers. For each greater tier of customer a supplier supplies, its rate of exit is reduced by approximately 58 percent \((1-e^{-0.870})\). Therefore, supplying the top tier (status equal to three, e.g. Ford) is associated with an exit rate approximately 18 percent relative to firms supplying only the minor independents (status equal to one, e.g. Dort). However, the coefficient for the interaction of clutches and status is also significant and of approximately the same magnitude but different sign. This indicates that increased status does not provide a benefit for clutch manufacturers. The non-significance of the coefficient for the interaction of clutch suppliers and autonomy indicates that both carburetor and clutch suppliers benefited from increases in autonomy.

The difference in the status result for clutch and carburetor manufacturers, with a significant reduction in risk for carburetors but not for clutches, bears comment here. The difference almost certainly arises from the difference in the complexity of the two products, combined with the conceptual basis of why status will sometimes influence survival. Throughout the study period, clutches were complex goods (Page, 1918; Dyke, 1923; Newcomb and Spurr, 1989). In turn, this complexity made evaluation of the quality of a given suppliers carburetors somewhat ambiguous for a customer that did not deal with the supplier. In such cases, the 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

---

1 We tested for sensitivity of the pooled sample by adding a variable that interacted the clutch suppliers with the duration variable. We omitted the interaction term from the reported results because it was highly non-significant.
in direct product assessment underlies the value of status. Clutches, by contrast with carburetors, had become relatively standard even by the beginning of the study period (Page, 1918; Dyke, 1923; Newcomb and Spurr, 1989). By about 1920, the relatively simple single-plate clutch had become the dominant choice of most automobile manufacturers. 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. Thus, the difference in the status results for carburetor and clutch manufacturers reinforces the source of the status advantage, which lies in providing a substitute for direct evaluation by potential customers in cases where such evaluation is difficult or impossible.

In parallel with the status differences, the equivalence of the autonomy result for clutch and carburetor suppliers also warrants comment. The significance of autonomy for both types of firms again speaks to the underlying source of the autonomy benefit. That is, whether a firm manufactures a complex good or a standardized good, having autonomy from the customers for that good helps the supplier maintain autonomy from its customers and, in turn, helps it survive. Autonomy, therefore, is beneficial to all firms, while customer status primarily benefits suppliers that produce goods that are difficult to evaluate.

Model six tests our fourth hypothesis, that autonomy is especially beneficial during adverse economic conditions. Note first that adverse economic conditions slightly increase the rate of exit, though this effect is not significant. However, the significant negative coefficient on the interaction of autonomy and adverse economic conditions indicates that increased autonomy can offset the impact of economic hardship. The magnitude of this interaction effect is much greater than the main effect of autonomy, which loses significance in the presence of the interaction term. To illustrate this effect, Figure 3 shows the effect of increases in autonomy throughout the analyses.
when one of the last three years have had decreasing sales (AEC=0.33) and when none of the last three years have had decreasing sales (AEC=0).

[Insert figure 3 about here]

Figure 3 indicates that the impact of autonomy is much greater during adverse economic conditions. In good economic times, corresponding to AEC=0, a firm with autonomy of 1.25 had an exit rate approximately 60% that of a firm with the minimal observed autonomy, 0.25. In poorer economic times, corresponding to AEC=.33, the exit rate of the firm with autonomy of 1.25 was only approximately 20% that of the firm with autonomy of 0.25. Therefore, the advantage provided by the additional autonomy is much larger in poor economic times, even if the overall rate of exit is higher under adverse economic conditions.

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. An 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 network characteristics affect supplier survival. Suppliers with higher autonomy and higher status experience higher survival chances.

In this paper we also explore 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 (Levinthal and Fichman, 1988; Baker, Faulkner and Fisher, 1998). Such tight coupling results when firms are strongly reliant on each other, often having many interdependent business systems and
interorganizational 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), and we did find that longer-term relationships with buyers enhanced the survival chances of suppliers.

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 should have adverse effects on firm performance because the focal supplier firm derives fewer control and information benefits from its network (Caves and Uekusa, 1976; Pfeffer and Salancik, 1978; Burt, 1992). These adverse effects are magnified when there is an environmental shock because the focal firm in a tightly coupled network has fewer alternatives to buffer itself against a shock. The network view, therefore suggests that suppliers that have higher structural autonomy are better able to withstand environmental shocks that affect the network. We find that suppliers with greater structural autonomy experience lower dissolution rates, especially in adverse environmental conditions.

Organizations that are embedded in tightly coupled networks find it difficult to adapt to environmental changes affecting any single member of the network (Simon, 1962; Weick, 1979, 185-187; Aldrich and Whetten, 1981:388). In the extreme case, selection itself may shift to a higher level and result in the failure of the entire network. The failure of entire industrial groups, chaebol, in South Korea during the recent economic crisis illustrates the risks associated with being embedded in tightly coupled networks. Longitudinal studies of network structure and organizational performance will help us understand both the evolution of an organization’s network structure and its effect on organizational performance.
Figure 1: Clutch firms by year
Figure 2: Carburetor firms by year
Figure 3: Effect of autonomy on exit rate
Table 1
Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>S.D.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (no. of firms)</td>
<td>9.3729</td>
<td>5.2177</td>
<td>2.0000</td>
<td>20.0000</td>
</tr>
<tr>
<td>Left-censored</td>
<td>0.2208</td>
<td>0.4152</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>Large supplier (=1)</td>
<td>0.5833</td>
<td>0.4935</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>Agg. prod. of cust. (millions)</td>
<td>1.2308</td>
<td>1.9177</td>
<td>0.0010</td>
<td>8.9139</td>
</tr>
<tr>
<td>Clutch supp. (=1)</td>
<td>0.3708</td>
<td>0.4835</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>Max. duration of cust. relationship</td>
<td>8.6500</td>
<td>8.9996</td>
<td>0.0000</td>
<td>41.0000</td>
</tr>
<tr>
<td>Autonomy</td>
<td>3.5692</td>
<td>6.8985</td>
<td>0.2500</td>
<td>58.1506</td>
</tr>
<tr>
<td>Prop. of cust. that are vert. int.</td>
<td>0.1369</td>
<td>0.2476</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>Status</td>
<td>2.2083</td>
<td>0.8635</td>
<td>1.0000</td>
<td>3.0000</td>
</tr>
<tr>
<td>Clutch * Status</td>
<td>0.6958</td>
<td>1.0653</td>
<td>0.0000</td>
<td>3.0000</td>
</tr>
<tr>
<td>Clutch * Autonomy</td>
<td>1.5207</td>
<td>5.5497</td>
<td>0.0000</td>
<td>58.1506</td>
</tr>
<tr>
<td>Adverse Economic Conditions (AEC)</td>
<td>0.3283</td>
<td>0.2116</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>AEC* Autonomy</td>
<td>1.1137</td>
<td>2.3093</td>
<td>0.0000</td>
<td>19.3642</td>
</tr>
<tr>
<td>Clutch * AEC</td>
<td>0.1229</td>
<td>0.2030</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>Clutch * AEC *</td>
<td>0.4844</td>
<td>1.8650</td>
<td>0.0000</td>
<td>19.3642</td>
</tr>
<tr>
<td>Variable</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>----------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>1. Density (no. of firms)</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Left-censored</td>
<td>0.45</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Large supplier (=1)</td>
<td>-0.60</td>
<td>-0.26</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>4. Agg. prod. of cust. (millions)</td>
<td>-0.52</td>
<td>-0.28</td>
<td>0.43</td>
<td>—</td>
</tr>
<tr>
<td>5. Clutch supp. (=1)</td>
<td>-0.04</td>
<td>-0.11</td>
<td>-0.06</td>
<td>-0.00</td>
</tr>
<tr>
<td>6. Max. duration of cust. relationship</td>
<td>-0.33</td>
<td>-0.17</td>
<td>0.29</td>
<td>0.60</td>
</tr>
<tr>
<td>7. Autonomy</td>
<td>0.16</td>
<td>-0.05</td>
<td>-0.11</td>
<td>-0.02</td>
</tr>
<tr>
<td>8. Prop. of cust. that are vert. integrated</td>
<td>-0.10</td>
<td>-0.13</td>
<td>0.14</td>
<td>0.27</td>
</tr>
<tr>
<td>9. Status</td>
<td>-0.46</td>
<td>-0.19</td>
<td>0.42</td>
<td>0.57</td>
</tr>
<tr>
<td>10. Clutch * Status</td>
<td>-0.23</td>
<td>-0.18</td>
<td>0.08</td>
<td>0.24</td>
</tr>
<tr>
<td>11. Clutch * Autonomy</td>
<td>0.03</td>
<td>-0.12</td>
<td>-0.12</td>
<td>-0.00</td>
</tr>
<tr>
<td>12. Adverse Economic Conditions (AEC)</td>
<td>-0.29</td>
<td>-0.11</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>13. AEC * Autonomy</td>
<td>0.06</td>
<td>-0.08</td>
<td>-0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>14. Clutch * AEC</td>
<td>-0.18</td>
<td>-0.16</td>
<td>-0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>15. Clutch * AEC * Autonomy</td>
<td>-0.02</td>
<td>-0.12</td>
<td>-0.09</td>
<td>0.02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Status</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Clutch * Status</td>
<td>0.09</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Clutch * Autonomy</td>
<td>0.02</td>
<td>0.41</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Adverse Economic Conditions (AEC)</td>
<td>0.16</td>
<td>0.06</td>
<td>-0.01</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. AEC * Autonomy</td>
<td>0.13</td>
<td>0.15</td>
<td>0.67</td>
<td>0.20</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Clutch * AEC</td>
<td>-0.17</td>
<td>0.72</td>
<td>0.26</td>
<td>0.37</td>
<td>0.14</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>15. Clutch * AEC * Autonomy</td>
<td>0.05</td>
<td>0.41</td>
<td>0.92</td>
<td>0.11</td>
<td>0.74</td>
<td>0.38</td>
<td>—</td>
</tr>
</tbody>
</table>
### Table 3

**Dissolution Rate Models for Carburetor and Clutch Suppliers, 1918-1972**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 0-5 yrs.</td>
<td>-1.266*</td>
<td>-1.130*</td>
<td>-0.123</td>
<td>0.409</td>
<td>1.235</td>
<td>1.654</td>
</tr>
<tr>
<td></td>
<td>(-0.601)</td>
<td>(0.612)</td>
<td>(0.649)</td>
<td>(0.781)</td>
<td>(0.916)</td>
<td>(1.062)</td>
</tr>
<tr>
<td>Age 6-10 yrs.</td>
<td>-2.211*</td>
<td>-1.506*</td>
<td>-0.178</td>
<td>0.340</td>
<td>1.290</td>
<td>1.794</td>
</tr>
<tr>
<td></td>
<td>(-0.683)</td>
<td>(0.725)</td>
<td>(0.828)</td>
<td>(0.937)</td>
<td>(1.069)</td>
<td>(1.187)</td>
</tr>
<tr>
<td>Age 11-15 yrs.</td>
<td>-2.755*</td>
<td>-1.537*</td>
<td>-0.281</td>
<td>0.163</td>
<td>1.311</td>
<td>1.885</td>
</tr>
<tr>
<td></td>
<td>(0.680)</td>
<td>(0.720)</td>
<td>(0.835)</td>
<td>(0.927)</td>
<td>(1.107)</td>
<td>(1.237)</td>
</tr>
<tr>
<td>Age 16+ years</td>
<td>-2.836*</td>
<td>-2.122*</td>
<td>-1.077</td>
<td>-0.546</td>
<td>0.365</td>
<td>0.769</td>
</tr>
<tr>
<td></td>
<td>(0.608)</td>
<td>(0.625)</td>
<td>(0.677)</td>
<td>(0.808)</td>
<td>(0.944)</td>
<td>(1.113)</td>
</tr>
<tr>
<td>Density (no. of firms)</td>
<td>0.008</td>
<td>0.025</td>
<td>0.041</td>
<td>0.036</td>
<td>0.028</td>
<td>-0.017</td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
<td>(0.040)</td>
<td>(0.039)</td>
<td>(0.039)</td>
<td>(0.042)</td>
<td>(0.044)</td>
</tr>
<tr>
<td>Left-censored</td>
<td>0.823*</td>
<td>0.786*</td>
<td>0.667*</td>
<td>0.726*</td>
<td>0.684*</td>
<td>0.595</td>
</tr>
<tr>
<td></td>
<td>(0.351)</td>
<td>(0.358)</td>
<td>(0.375)</td>
<td>(0.382)</td>
<td>(0.391)</td>
<td>(0.397)</td>
</tr>
<tr>
<td>Large supplier (=1)</td>
<td>-0.459</td>
<td>-0.463</td>
<td>-0.584*</td>
<td>-0.593*</td>
<td>-0.525</td>
<td>-0.678*</td>
</tr>
<tr>
<td></td>
<td>(0.344)</td>
<td>(0.347)</td>
<td>(0.344)</td>
<td>(0.346)</td>
<td>(0.348)</td>
<td>(0.367)</td>
</tr>
<tr>
<td>Agg. prod. of cust. (millions)</td>
<td>-1.055*</td>
<td>-0.711</td>
<td>-1.076*</td>
<td>-0.628</td>
<td>-0.271</td>
<td>-0.126</td>
</tr>
<tr>
<td></td>
<td>(0.481)</td>
<td>(0.463)</td>
<td>(0.558)</td>
<td>(0.616)</td>
<td>(0.594)</td>
<td>(0.571)</td>
</tr>
<tr>
<td>Clutch supplier (=1)</td>
<td>0.434</td>
<td>0.095</td>
<td>-0.062</td>
<td>-0.159</td>
<td>-1.627</td>
<td>-0.269</td>
</tr>
<tr>
<td></td>
<td>(0.314)</td>
<td>(0.328)</td>
<td>(0.345)</td>
<td>(0.355)</td>
<td>(1.014)</td>
<td>(1.411)</td>
</tr>
<tr>
<td>Max. duration of cust. relationship</td>
<td>-0.212*</td>
<td>-0.099*</td>
<td>-0.083</td>
<td>-0.094</td>
<td>-0.126*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.061)</td>
<td>(0.058)</td>
<td>(0.057)</td>
<td>(0.059)</td>
<td>(0.064)</td>
<td></td>
</tr>
<tr>
<td>Autonomy</td>
<td>-1.374*</td>
<td>-1.371*</td>
<td>-1.376*</td>
<td>-0.503</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.375)</td>
<td>(0.377)</td>
<td>(0.472)</td>
<td>(0.509)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prop. of cust. that are vert. int.</td>
<td>0.392</td>
<td>0.561</td>
<td>0.455</td>
<td>0.437</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.479)</td>
<td>(0.489)</td>
<td>(0.526)</td>
<td>(0.530)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status</td>
<td>-0.363</td>
<td>-0.870*</td>
<td>-0.974*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.292)</td>
<td>(0.384)</td>
<td>(0.392)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clutch supplier * Status</td>
<td>0.957*</td>
<td></td>
<td>.873*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.437)</td>
<td></td>
<td>(0.466)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clutch supplier * Autonomy</td>
<td>0.063</td>
<td>-0.989</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.747)</td>
<td></td>
<td>(1.205)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adverse Economic Conditions (AEC)</td>
<td></td>
<td></td>
<td></td>
<td>1.794</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.071)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AEC* Autonomy</td>
<td></td>
<td></td>
<td></td>
<td>-4.009*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.217)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clutch supplier * AEC</td>
<td></td>
<td></td>
<td></td>
<td>-4.723</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(3.451)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clutch supplier * AEC * Autonomy</td>
<td></td>
<td></td>
<td></td>
<td>4.412</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(4.250)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-121.657</td>
<td>-113.758</td>
<td>-97.588</td>
<td>-96.782</td>
<td>-94.433</td>
<td>-91.128</td>
</tr>
</tbody>
</table>

* p < .05, one-sided tests
*Standard errors are in parentheses. Total of 480 spells and 48 events (dissolutions)
REFERENCES


Dyke, Andrew Lee. 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.


Helper, Susan. 1987. Supplier relations and innovatoin in the auto industry, Harvard University.


