Acknowledgements: We appreciate comments on earlier versions of this paper provided by Ron Burt, Glenn Carroll, Shin-Kap Han and participants at the 2000 Organization Science Winter Conference in Keystone, Colorado.
Almost every business network exists in the context of a larger population of similar organizations, but research has not produced a clear understanding of how similar firms outside a focal network influence the performance of network members. We use the term extra-network firms to refer to firms that are similar to those in the focal firm’s network, but to which the focal firm is not tied. The existing literature offers two conflicting arguments and sets of results concerning extra-network firms. One approach views the ties that exist between organizations as paramount and finds little empirical impact of extra-network firms. The second approach, based on the concept of structural autonomy, takes into account the opportunities that exist outside of the network of ties, and finds a constant moderating effect of extra-network firms on organizational action and performance. Using data on buyer-supplier relationships in the automobile industry, we help resolve this conceptual and empirical conflict by arguing that the impact of extra-network firms varies inversely with the relationship-specificity of network ties. Either ignoring extra-network firms or incorrectly attributing a constant moderating effect to them can lead to a dramatically incorrect understanding of how network relationships affect firm performance.

Keywords: Networks, buyer-supplier relationships, structural autonomy
Almost every network of business relationships exists in the context of a larger organizational population. For example, a supplier normally sells to some, but not all, of the buyers to which it might potentially sell goods and services. The buyers, in turn, purchase goods from some, but not all, of their potential suppliers. The existing literature on interfirm relationships offers conflicting arguments and results about the significance of these potential ties, which we term extra-network firms. Some work sees the ties that exist between organizations as paramount, so that extra-network firms are generally beyond theoretical consideration (e.g. Gulati 1996). In other studies, extra-network firms enter the frame of reference, but empirical testing generally finds them irrelevant (Darr, Argote, and Epple 1995; e.g. Davis 1991). In contrast, the structural autonomy literature emphasizes the need to understand the opportunities that exist outside a focal firm’s current ties in order to understand the impact of an organization’s network (Burt 1992). Both approaches suffer from a common limitation, however, because they assume that any extra-network influence will produce a constant effect on focal firm performance. Neither approach addresses differences in the nature of network relationships.

This paper argues that either ignoring extra-network firms or assuming an unvaried relevance produces misleading conclusions about firm performance. This is a more focused point than the general problem of defining the boundary for a network study (Scott 1991:56-58). We take a market-defined boundary of a population of organizations (Scott 1991:56-58), which in our case includes American automobile manufacturers and suppliers of two types of components, carburetors and clutches, from 1918-1937. We ask whether, in order to understand a focal firm’s performance, we can limit ourselves to examining its ties with current partners or if the characteristics of other American automobile manufacturers and suppliers are also relevant. We introduce the term extra-network firms to refer to those firms that are within the defined population of relevant firms, but do not have ties to the firm or firms of focal interest. We argue that the significance of extra-network firms varies inversely with the relationship-specificity of network ties and potential ties. Our central contribution is to elaborate how networks affect firm performance by considering the contingent effect of extra-network firms.

BACKGROUND: CONFLICTING VIEWS ON EXTRA-NETWORK FIRMS

A firm’s ties to other organizations affect its behavior and performance along multiple dimensions. Research issues have ranged from the impact of direct dyadic ties to the effect of the overall structure of a firm’s network. This section briefly reviews the vast literature. We use representative
studies to illustrate the varying treatment of extra-network firms and the impact the treatment has on our understanding of networks’ significance to their constituent organizations. Our point is not that any one of these studies has been wrong in its treatment, but rather that no consistent theoretical basis guides the treatment of extra-network organizations across studies. For simplicity, we frame our discussion in terms of firms, but we draw on the more general literature on organizational and individual networks.

While reviewing the wide range of studies that have examined interfirm relationships, we could not identify a single term that is consistently used to describe those firms that are within the defined population of relevant firms, but are not currently tied to the firm or firms of focal interest. We chose the term "extra-network", realizing that much of the inter-firm relationship literature focuses on dyadic relationships rather than on overall networks, while much of the formal social network literature applies an encompassing definition of networks so that few firms are considered “extra-network”. However, our theoretical interest is relevant across the broad span of work on interfirm relationships. Indeed, the confusion of language points to a valuable opportunity for conceptual clarification.

The differences we observe in the treatment of extra-network firms are not merely an issue of empirical measurement. Network measures are closely entwined with underlying theory. For example, each of the nine measures for “centrality” that can be calculated by UCINET are based on specific theoretical assumptions about what makes an actor “central” to a network. Similarly, Burt points out that different versions of his measure for constraint have drawn differentially on various theoretical approaches and focused attention on different aspects of networks’ effects (Burt 1992:278, note 8). Thus, empirical differences among various network studies reflect differences in underlying, often implicit, theoretical assumptions.

The most direct influences of inter-firm relationships arise at the level of the dyad, considering each of a focal firm’s relationships with other firms individually. For example, a rich literature demonstrates that learning occurs across firms that are directly linked through ownership (Darr, Argote, and Epple 1995) or interlocking boards of directors (Davis 1991). Research has also found that ties between two firms contribute to improved performance in cooperative ventures (Dyer 1996; Uzzi 1996), similarity in political behavior (Mizruchi 1992), and a greater likelihood of future collaboration (Gulati 1995) or exchanges (Hoetker forthcoming).
Indirectly linked actors, that is, those that do not have direct ties to the focal actor, but do have ties to one of the focal actors’ partners (or through even longer chains of ties), can also be influential. For example, Granovetter (1973) found that information about potential employment often originated not from a direct tie, such as a friend, but rather from a person tied to that friend, with information sometimes traversing multiple indirect ties. At the firm level, ties to a partner can provide access not only to that partner’s knowledge, but also to that of the partner’s partners (Gulati and Gargiulo 1999). Mizruchi (1992) found that two firms that each had a member of their board of directors who also sat on the board of a common third firm tended to have similar patterns of political contributions.

Simultaneously considering all of a firm’s direct and indirect ties allows consideration of how the overall structure of a firm’s network affects its behavior and performance. Firms that occupy a central position in a network via their linkages to other firms have greater access to information (Useem 1984) and greater status (Bonacich 1987; Podolny 2001). Firms with networks rich in structural holes, that is, focal firms that are tied to a large number of firms that themselves are not tied to each other, benefit from privileged access to a range of non-redundant information (Burt 1992).

Most of these studies have focused only on the focal firm’s existing network of direct and indirect ties. For example, Gulati (1996) examined the likelihood of alliance formation as a function of existing direct and indirect ties, but did not consider whether the number of potential alliance partners outside a firm’s current network affected the likelihood of a potential alliance being formed.

A few studies have considered the possible influence of firms beyond the focal firm’s network, but have found no effects. For example, Darr et al (1995) found that the performance of pizza restaurants correlated with performance of restaurants with which they shared ownership ties (within-network firms), but did not correlate with the performance of restaurants in the same geographic area that did not have common ownership (extra-network firms). Davis (1991) found that the likelihood a firm would adopt a “poison pill” provision was influenced by its direct ties to prior adopters and its centrality in its network of firms, but not by the number of firms in the entire population that had adopted such a provision (predominantly extra-network firms).

Another strand of the literature on interfirm relationships, however, posits an important role for the population of extra-network firms. Formalizing ideas from the resource dependency literature (Pfeffer and Salancik 1978) in the context of networks (Burt 1982; 1992) developed the concept of structural
autonomy. Structural autonomy flows from occupying an advantageous network position relative to other actors such that the focal actor can either play other actors off against each other to obtain superior results in negotiations or profit by providing referrals between actors. A firm lacking structural autonomy is constrained by its exchange partners, who may take advantage of the dependence to extract economic rents, limit its ability to form new ties, or otherwise disadvantage it (Baker 1990). A firm with high structural autonomy can resist the demands of its exchange partners. Consequently, structural autonomy, i.e., the lack of constraint, leads to superior performance (Burt 1992; Burt, Guilarte, Raider, and Yasuda 2002).

Structural autonomy depends on the balance of three types of constraint. We will use buyers and suppliers as an example. First, a supplier is constrained by its relationship with a buyer to the degree that the buyer represents a large proportion of the focal firm’s sales. Second, the presence of buyers to which a supplier does not currently sell, but to which it could, moderates the negative effect of the first constraint on the supplier’s autonomy. Third, the supplier is constrained to the degree that its buyers could replace it with other suppliers. Combining the three constraints posed by all of a supplier’s buyers and potential buyers yields its overall autonomy.

The concept of structural autonomy encompasses extra-network firms in its second and third components. The argument suggests that no matter how poor a firm’s position in its network of current exchanges, it is better off if there are alternative partners available in the population. Conversely, no matter how good a firm’s position in its network of current exchanges, it is worse off if its exchange partners have many opportunities to replace it. By this logic, while having only one buyer is a vulnerable position for a supplier, it is less so if there are many other potential buyers. Similarly, having many buyers does not guarantee that a supplier will have an advantageous position if buyers can shift to other suppliers in the population to replace the focal supplier. In Burt’s 1992 formulation (1992:Eq. 2.7), the impact of current relationships and the availability of alternative partners are multiplicatively combined into a single term (“C”). In other words, the approach assumes that the availability of buyers outside the supplier’s network of current exchanges always moderates the impact of current exchanges to the same degree.

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1 Following our initial definition, we define these alternative partners as “extra-network”, since they are within the population of potential partners, but not currently tied to the focal firm. In Burt’s terminology, they could be considered part of a firm’s “network” because he includes current and potential partners within the same broad conceptual scope, as we describe in the text.
Thus, the literature on interfirm relationships contains conflicting treatments of extra-network firms: they have been ignored, considered but found not to matter, or assumed to have a constant effect across settings. Two representative papers further illustrate this conflict.

The first example paper predicted an influence but found no impact of extra-network firms. Baker, Faulkner, and Fisher (1998) analyzed the dissolution of market ties between advertising agencies and their clients. They considered the effects of competition, power, and institutional forces. We focus on two of their competition results. They find that a client’s ties to any given agency are more likely to dissolve in the next year when it currently uses many agencies. They interpret this as being the effect of the client having many alternatives with which it already deals (pg. 155). However, the ratio of agencies to clients in a given year does not influence the likelihood that a tie will dissolve. This was contrary to their expectation that clients were more likely to break their ties to agencies when they had an “abundance of alternatives” (p. 155). Although Baker et al. do not frame it as such, the first finding is a feature of the client’s existing network of ties, while the second is a function of the entire buyer-supplier population, consisting predominantly of extra-network firms. The presence of extra-network potential partners, it appears, did not encourage firms to leave their current partners in this setting.

The Baker et al. (1998) empirical finding stands in interesting contrast to the assumptions of Burt’s structural autonomy work, which expects extra-network firms to have a constant effect on firm performance. We focus on his study of the relationship between product networks and market profit (1992:Ch. 3). Working at the level of product markets, Burt hypothesizes that suppliers in a market will have a higher profit margin when buyers are unable to easily replace them (“O”, for supplier “opportunity” in Burt’s formulation) and decrease when they are constrained by their relationships with buyers (“C”, for supplier “constraint”). He finds evidence for both hypotheses using data on 77 product markets as defined by the Department of Commerce benchmark input–output tables from 1963 to 1977.

We are particularly interested in the latter hypothesis in Burt’s (1992) work, which focuses on the constraint the buyers impose on suppliers in a given market. Burt measures this constraint as the multiplicative combination of the degree to which suppliers depend on buyers in a given market and the degree to which suppliers can find alternative buyers in that market. In other words, the availability of extra-network buyers moderates the negative effect of dependence on buyers currently in a supplier’s network.
There is an intriguing tension between the Burt (1992) and Baker et al. (1998) findings concerning what we refer to as extra-network firms. Burt posits that extra-network buyers moderate the constraint of a supplier’s poor network position because alternative buyers strengthen the supplier’s negotiating position vis-à-vis its current buyers. This strengthening will only occur, of course, to the degree that forming new relationships is a credible possibility. Baker et al.’s results suggest that firms will shift business among existing partners, but that extra-network firms are not sufficiently attractive alternatives to cause firms to shift business from existing partners. This calls into question whether the presence of extra-network partners creates a sufficiently credible alternative to strengthen a firm’s negotiating position. In the next section, we develop theory that attempts to resolve the tension between previous findings on the influence of extra-network actors on firm performance.

RESOLVING THE CONFLICT: CONTINGENT EFFECTS OF EXTRA-NETWORK FIRMS

We argue that the role of extra-network firms is contingent on the content of the ties that constitute a meaningful network in a given setting. At the heart of all studies of interfirm relationships is the belief that a “tie” between two organizations, whatever that signifies in a given environment, changes their interaction. We focus on three changes -- trust, mutual knowledge, and inter-firm routines -- that a broad spectrum of the interfirm relationship literature have identified as important.

Trust is an important aspect of many ties (Coleman 1988). Trust develops between individuals engaged in repeated exchanges (Uzzi 1996). This trust can become institutionalized, leading to trust between the organizations that endures despite changes in the individuals involved (Zaheer, McEvily, and Perrone 1998). Trust allows organizations to mitigate concerns of opportunistic behavior and to coordinate their activities more effectively (Gulati and Singh 1998). Trust also supports the flow of tacit, fine-grained knowledge between firms (Ingram and Roberts 2000; Uzzi 1996).

Inter-firm ties often also imply greater mutual knowledge of each partner’s routines and capabilities because collaborative processes lead to interaction of people from the partner firms (Ring and Van de Ven 1994). Larson, Bengtsson, Henriksson, and Sparks (1998) show that such knowledge can serve as the basis for coordinating joint activities. Dussauge, Garrette and Mitchell (2001) show, in a study of international alliances, that firms’ ability to reduce costs, increase quality, and achieve greater timeliness increases as partners learn from each other and about each other.
Lastly, ties may generate beneficial routines that span the partner firms (Cyert and March 1963; Nelson and Winter 1982). Examples of such routines include a common language for discussing technical issues, systems for exchanging information and personnel, just-in-time delivery systems and cooperation in product development (Martin, Swaminathan, and Mitchell 1998; Mitchell and Singh 1996).

Each of these changes is specific to a given relationship. Interacting with a firm increases trust in that firm, but not in others. Similarly, a firm cannot transfer its knowledge of a partner’s capabilities to other partnerships. Nor do inter-firm routines developed in one partnership transfer cleanly to others.

Our central insight is that these changes may not be equally relevant to the dominant activity in a network. The effect of extra-network firms on the focal firm’s behavior and performance is contingent on the relevance of the relationship-specific changes that occur within inter-firm ties.

For example, if the exchanges that occur in a given setting can easily take place even in the absence of trust, the mere fact that an organization is trusted by virtue of an inter-organizational tie does not significantly distinguish that organization from other potential partners. For instance, extra-network organizations may be viable exchange partners, even though there is no network-based basis for trust with them. Accordingly, the impact of existing ties can only be understood in the larger context of the entire population of potential partners. When trust is vital to an exchange, however, an organization is unlikely even to consider an extra-network organization as a partner. As a result, it is theoretically and empirically sufficient to study only existing ties.

We formalize this insight by developing hypotheses in the context of buyer-supplier networks, examining the potential impact of structural autonomy on supplier performance. Suppliers are highly relevant examples of firms that operate in business networks with substantial variation in structural autonomy. Thus, supplier performance provides an appropriate measure for examining extra-network influences. In the discussion section, we consider how our findings generalize beyond buyer-supplier networks, particularly into settings where structural autonomy is not the dominant concern.

We state the predictions concerning supplier performance in terms of business failure (i.e., dissolution). Financial performance measures are not available for our analysis. Business dissolution is a strong indicator of financial problems, however, particularly in commercial contexts in which business divestiture offers an alternative means by which successful firms can chose to exit an industry for strategic reasons.
A supplier is constrained by its network of existing ties to buyers when its sales are concentrated to few buyers. Because it is vulnerable to having a major buyer take its business elsewhere, the supplier is in a weak bargaining position vis-à-vis its major buyers. Buyers are likely to take advantage of this dependence in ways that are detrimental to the supplier (Baker 1990; Burt 1992). 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.

**Hypothesis 1.** The more constrained a supplier is by its ties to buyers, the more likely it is to fail.

We next consider the role of extra-network firms, starting with buyers outside the supplier’s network. The presence of potential buyers beyond those with which a supplier already trades would appear to increase the alternatives available to a given supplier, strengthening its negotiating position with existing buyers (Burt 1992). In essence, a supplier with only one buyer is severely constrained by that buyer, but the presence of many potential buyers mitigates that constraint to some degree.

We argue, however, that this moderating effect exists only to the degree that the option of switching to an extra-network buyer is credible. When the exchanges that take place between a buyer and supplier are highly dependent on the relationship-specific changes associated with prior exchanges, switching to an extra-network buyer incurs a substantial cost. Until the new buyer and supplier develop trust in each other, they will be more concerned that the other firm might act opportunistically and will need to employ more elaborate and costly governance mechanisms (Gulati and Singh 1998). The lack of knowledge about a partner’s capabilities raises the risk of choosing a partner of low quality (Rangan 2000). Without established routines for dealing with each other and lacking knowledge of each other’s operating procedures, the buyer and supplier will suffer higher coordination costs and/or diminished performance in cooperative tasks (Singh and Mitchell 1996). These costs make the prospect of replacing an existing buyer with a new buyer unattractive at best and infeasible at worst. Thus, the existence of extra-network buyers neither strengthens a supplier’s bargaining position nor relieves it of dependence on its existing buyers when relationship-specific factors are important.

However, not all exchanges benefit meaningfully from trust, mutual knowledge and inter-firm routines. A simple contract may provide a low-cost alternative to trust when the good being transacted is
simple and it is straightforward for the firms to specify the various aspects of the exchange, e.g., performance levels and delivery times. When there is little inter-dependence between the component and the buyer’s end-product, there is less need for communication and coordination between buyer and supplier (Galbraith 1977; Thompson 1967). As a result, the lack of mutual knowledge, a common technical language, and inter-firm coordination routines imposes little or no penalty (Gulati and Singh 1998). Under these conditions, replacing a current buyer with a new one is a credible option, which strengthens a supplier’s bargaining power with existing buyers and provides alternatives should negotiations fail:

**Hypothesis 2.** The less that exchanges benefit from relationship-specific aspects of buyer-supplier ties, the more the presence of extra-network buyers will reduce the impact of constraint from current ties to buyers.

The same logic applies to the other set of extra-network firms: other suppliers. In the abstract, the presence of many alternative suppliers would appear to make a supplier less autonomous. If the supplier does not yield to a buyer’s demands, the buyer can replace the supplier with another (Burt 1992). However, this effect obtains only to the degree that buyers would actually be willing to make such a switch. When exchanges benefit greatly from trust, mutual knowledge, and inter-firm routines, buyers may find it preferable to yield some negotiating position, rather than lose the benefits of continuing to work with a given supplier. Accordingly, the presence of other suppliers will have minimal impact on a supplier’s autonomy. When exchanges do not depend on the relationship-specific benefits of ties, however, buyers have potential to switch and suppliers lose autonomy in the presence of many alternative suppliers:

**Hypothesis 3.** The less that exchanges benefit from relationship-specific aspects of buyer-supplier ties, the more the presence of alternative extra-network suppliers will increase the likelihood of a supplier failing.

In summary, we propose that the impact of extra-network firms on supplier performance is contingent on the nature of the exchanges that take place between buyer and supplier. The network of existing ties is the dominant determinant of supplier performance when these exchanges benefit from the development of relationship-specific trust, mutual knowledge, and inter-firm routines. When exchanges
do not benefit from these factors, however, we can only understand the impact of the network of existing ties by placing it in the context of the larger population of buyer and suppliers in which it is embedded.

There is an important contrast between our hypotheses and prior work on structural autonomy. Prior studies of structural autonomy have focused on the degree to which cohesion among firms of the same “status” or type, e.g., buyers, affects the ability of a partner to replace one firm with another. For example, when buyers are highly cohesive, theory suggests that they will resist a supplier’s efforts to pressure their existing buyer by negotiating with an alternative buyer (an extra-network buyer in our terminology, since it is a potential, but not current, partner for the supplier). This cohesion reduces the degree to which the presence of extra-network buyers relieves the constraint caused by the supplier’s current ties.

The autonomy literature assumes that, at a given level of cohesion, a potential partner always provides the same degree of relief from constraint. Our theoretical interest is in whether the relief provided is contingent on the nature of the exchanges that take place between buyer and supplier.

We note that the discussion of small numbers bargaining in transaction cost economics (Williamson, 1985) offers a complementary argument to our predictions. Concerns about small numbers bargaining arise when a firm has few alternative suppliers for transaction specific exchanges. This condition is close to the situation in which there is relationship-specificity. That is, firms will be most affected by their relationships with actual suppliers for relationship-specific products, while they will be able to take potential suppliers into account for more general products. At the same time, transaction cost economics has only tangential application to our argument because we are focusing on relationships involving sets of exchanges rather than single transactions and because we are addressing the performance outcome of relationships rather than the formation of relationships, which is the primary focus of transaction cost economics.

METHODS

Empirical Setting

To test the contingent nature of inter- and extra-network organizations, we need sets of exchanges that benefit differentially from the relationship-specific advantages of ties, but are otherwise as similar as possible. Furthermore, since our interest is in the impact of extra-network firms, we need data on the entire population of buyers and suppliers.
The early U.S. automotive supply industry fulfils these requirements. We study exchanges between automotive assemblers and suppliers of two components, clutches and carburetors, from 1918-1937. The value of relationship-specific ties varies for each component, as we discuss below. Data is available on the full population of buyers and suppliers. We control for many potentially confounding factors by holding the time-frame, buyer population, and institutional environment constant across the two components. The longitudinal nature of the data provides variation in the populations of buyers and suppliers. Careful review of the copious information available on the early automotive industry and its subsequent development reveals no idiosyncratic factors that would invalidate generalization of our findings to other modern or historical settings.

We use carburetors as examples of exchanges that benefit from the relationship-specific aspects of ties and clutches as examples of exchanges that do not. Carburetor design and production required customization to and of automobile ignition systems, fuel systems, power train, and other automobile characteristics. Throughout the study period, carburetors were complex goods (Dyke 1923; Page 1918). As Newcomb & Spurr (1989) noted, "even in the 1960s, the design of the [carburetor] system was still very much a matter of trial and error, and the final design largely a matter of compromise. A layout that could suit one engine might give poor results on another." Inter-firm coordinating routines were important to ease the management of the high level of interdependence between the carburetor and the rest of the automobile’s design. Because it was difficult to contract for all of the eventualities that might develop over the design and production of a carburetor, it was hard to replace trust as the basis for transacting. Lastly, this complexity made evaluation of the quality of a given supplier’s carburetors ambiguous for a customer that did not deal with the supplier.

Clutches, by contrast with carburetors, had become relatively standard by the beginning of the study period. Even before 1920, Page (1918:635) noted, "friction clutches are simple in form, easily understood, and may be kept in adjustment and repair without difficulty." By about 1920, the relatively simple single-plate clutch had become the dominant choice of most automobile manufacturers and required little customization for specific automobile models (Dyke 1923). Newcomb & Spurr (1989:221) stated that "once established [by about 1919] the basic principles of the clutch remained unchanged for many years" There was relatively little need for coordination between supplier and buyer and contracting was straight-forward, reducing the benefit of relationship-specific knowledge, trust, and routines. The
primary benefits that derived from sales of clutches were revenues, which occurred immediately upon selling clutches to an assembler, whether it was a current or new buyer.

We collected the primary data from the annual *Statistics and Specifications* issue of *Automotive Industries*. *Automotive Industries* identifies first-tier suppliers, which are the firms that sold components directly to assemblers, listed by automobile model. Since *Automotive Industries* provided specifications at the level of the division or model without listing the overarching company, we used information from Bailey (1971), Smith (1968), Mandel (1982), Gunnell (1982), and Kimes (1989) to construct life histories of assemblers and to connect divisions and models to the appropriate company. After aggregating the data upwards from the model and division levels to the firm level, we constructed the matrix of ties between supplier firms and buyer firms for carburetors and clutches for each year. Although *Automotive Industries* produced the *Statistics and Specifications* issue until 1972, coverage of specific components varied over time. We ended our analysis in 1937, the last pre-War year in which independent manufacturers of both components were listed. We did not include post-War data because of the dramatic changes in industry conditions during and after the Second World War, particularly consolidation among customers and suppliers that meant there were few entries and exits from the component sectors that we study.

*Automotive Industries* professes to list every model of automobile produced in the United States. This allows us to define the entire population of relevant firms, 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.

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

**Statistical Method**

We model supplier failure, defined as a supplier shutting down its production in the automotive carburetor or clutch market, using a piecewise exponential model. The model is extremely flexible with respect to the form of age dependence, about which we have no theoretical prediction. The model is also appropriate in the presence of left censoring (Barnett and Hansen 1996; Guo 1993), which is a characteristic of our sample.

The instantaneous rate of supplier dissolution or hazard rate, \( r(t) \), is

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

(1)

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

\[
r(t) = r(t)^* \exp(\beta x_i)
\]

(2)

where \( r(t)^* \) is the baseline hazard rate that is constant within each of multiple time periods, but varies across periods, \( x_i \) is a matrix of variables describing supplier \( i \), and \( \beta \) is a matrix of parameters to be estimated.

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

Our data are annual, so we update all time-varying covariates each year. We treated each annual spell as right-censored, except those spells that ended with the dissolution of the supplier. Following Petersen (1991), we treated dissolutions as having occurred midway though the year to reduce potential estimation bias. A small number of divestitures also occurred during the study period (11 carburetor suppliers and 6 clutch suppliers), which we treated as censoring events because there were too few cases to treat divestiture as a competing risk. Conceptually, divestitures tend to result from different influences than dissolutions, so that it would not be appropriate to pool dissolutions and divestitures into a single class of business exits.
Because we observe multiple annual spells for each supplier, we use a shared frailty model (Clayton 1978; Gutierrez 2002). In a shared frailty model, each supplier \( i \) is assumed to have a hazard rate of

\[
R_i(t|\alpha_i) = \alpha_i r_i(t)
\]  

for \( i=1 \) to \( n \) where \( r_i(t) \) is the hazard rate as computed in Equation (2) and \( \alpha \) is some random positive quantity with mean one and variance \( \theta \). Suppliers for which \( \alpha \) is greater than one have an increased rate of failure (are more frail) for reasons not explained by the covariates. Similarly, those with \( \alpha \) less than one have a decreased rate of failure. This model allows for dependence across all observations of a supplier and may be thought of as the survival analysis equivalent to a random effects model in standard regression. Analyses commonly use the gamma and inverse Gaussian distributions for \( \alpha \). We report models with a gamma-distributed heterogeneity term, though we also estimated models with an inverse Gaussian distribution for \( \alpha \) to check the robustness of our results. We found no evidence of unobserved heterogeneity in supplier dissolution rates, suggesting that unobserved differences among suppliers are not driving our results. Estimating a standard survival model and adjusting the standard errors to account for possible correlation between observations for a supplier yields the same substantive results.

We estimated separate failure rate models for the two populations of suppliers. There are only two cases of firms manufacturing both carburetors and suppliers. Collapsing the two organizational populations into one would constrain the effects of firm and industry-level variables to be equal across the two populations, which would be an unwarranted assumption. For carburetor suppliers, there were 205 firm-year observations involving 35 suppliers between 1918 and 1937. Of these, 24 suppliers exited through dissolution. For clutch suppliers, there were 130 firm-year observations involving 30 suppliers between 1918 and 1937. There were 23 dissolutions. These counts do not categorize assemblers that vertically integrated into production of the components as suppliers. We considered these assemblers in our calculations of autonomy, as we describe 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.
Data and Measurements

We take as our starting point Burt’s (1992) measure of structural autonomy. The first component of autonomy is constraint from current exchanges. Supplier \( i \), our focal firm, is constrained by buyer \( j \) to the degree that \( j \) represents a large share of its sales, \( z_{ij} \). Ideally, we would know the dollar amount of a supplier’s sales to each buyer. Lacking this data, we set \( z_{ij} \) to one divided by the number of buyers to which supplier \( i \) sells in the current year.\(^3\) Summing the squared value of \( z_{ij} \) over all of supplier \( i \)’s buyers yield the total constraint placed on supplier \( i \) by its buyers in a scale of near 0 (little constraint due to having many buyers) to 1 (high constraint due to having only one buyer). However, the presence of extra-network buyers may moderate this constraint. We represent this moderating factor on a scale from near 0 (many extra-network buyers) to 1 (few extra-network buyers) by calculating

\[
1 - \frac{\text{Number of extra-network buyers}}{116}
\]  

(4)

where 116 is the maximum number of buyers present in any single year in our data.

To investigate our key theoretical concern, the potentially contingent effects of extra-network actors, we make a key change to Burt’s original formula. In Burt’s formulation, the presence of extra-network buyers—\( O_j \) as discussed on page 63-64 of Burt (1992)—always moderates the impact of constraint from current exchanges and always does so to the same degree (see equation 2.7 on page 64 of Burt (1992)).\(^4\) As detailed in the Appendix, however, we disaggregate the two factors, generating variables to test our first two hypotheses. The first, relating to Hypothesis 1, measures the loss of autonomy due to constraint from current exchanges. A significantly positive coefficient for this variable would confirm the Hypothesis. The second, relating to Hypothesis 2, measures the degree to which the presence of extra-network buyers relieves the constraint from current exchanges. A positive coefficient

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\(^2\) Burt has suggested other functional forms for structural autonomy in other work (e.g., Burt 1982). We use his 1992 measure because it has been more broadly applied.

\(^3\) Measuring sales volume would provide a more fine-grained measure of autonomy. We are unaware of any large-scale, longitudinal study that uses firm-level sales data as a measure of inter-firm relationships, however, because of a lack of access to such data. Burt (1992) uses industry-average sales data, while Uzzi (1996) and Baker, Falkner, and Fisher (1998) each have firm-level sales data for a single year. Thus, following other work (including Hypotheses C1 and C4 of Baker, Faulkner and Fisher, 1998), we use a measure based on the number of buyers and suppliers. Fortunately, this measure is both theoretically appropriate and empirically consistent. Theoretically, in terms of trust, mutual knowledge, and routines, there is a step-function between having a relationship and not having one. Empirically, our measure and a measure using exchange volume data would correlate strongly. On average, a firm with ten customers will be less constrained by each than a firm with two customers. A similar logic informs work by Gulati (1995; 1996), which uses a count of prior alliances rather than detailed data on their strength.

\(^4\) Because of the lack of ties among buyers in our empirical setting, \( O_j \) is strictly a function of the number of buyers to which the supplier does not currently sell.
for this variable indicates that extra-network buyers reduce the impact of constraint from current buyers. Hypothesis 2 predicts that this coefficient should be more positive for clutch suppliers than for carburetor suppliers.

The remaining component of autonomy, relating to Hypothesis 3, is the availability of other suppliers with which the focal supplier’s buyers could replace it, \( O \), in Burt’s terms (Burt 1992:71-72). Following Burt, we represent this on a scale from near 0 (low constraint due to few alternative suppliers) to 1 (high constraint due to many alternative suppliers).\(^5\) We do so by dividing the number of suppliers in a given year by the maximum number of suppliers present in any single year in our data (18 for clutches, 19 for carburetors). A positive coefficient for this variable would indicate that the presence of extra-network suppliers reduced the autonomy of the focal supplier. Thus, Hypothesis 3 predicts that this variable will have a more positive coefficient for clutch suppliers than for carburetor suppliers. The Appendix contains additional details on the calculation of the autonomy measures.

To control for variation in demand conditions, we include the total U.S. vehicle production in each year. This variable (from the Statistics and Specifications issue of Automotive Industries) helps control for the possibility that suppliers are more likely to fail when they face adverse demand conditions, which is especially important given the economic disruption of the Great Depression.

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

We also include a variable indicating the nature of a supplier’s customers. The contemporary literature clearly indicated that there were three distinct groups of assemblers by 1918: (1) the major assemblers (Ford, General Motors and, following the acquisition of Dodge, Chrysler); (2) the major independents, which we referred to by that term (e.g., Hudson and Packard); and (3) minor independents

\(^5\) Because of the lack of ties among suppliers in our empirical setting, this term is strictly a function of the number of suppliers. See Burt (1992:63).
(all others, e.g., Dort and Geronimo). We assigned each assembler to one of the three categories based on Kennedy’s (1941) year-by-year commentary, supplemented by Smith (1968).

Given the economic insignificance of the minor independents—in 1919, they collectively represented only twenty-five percent of U.S. automotive production (Kennedy 1941:105)—we assume that suppliers that sold only to the minor independents were among the least capable. The minor independents also offered the supplier little imprimatur of quality and provided minimal resources and expertise.

Lastly, we take a measure of supplier size from the *Thomas Register of American Manufacturers*, which reports firm capitalization. Suppliers in our sample range from size E (capitalization of $5,000-$9,999) to AAAA (capitalization greater than $1,000,000). Our size variable, Large Supplier, takes a value of 1 if the supplier is in the category AAA ($500,000 to $1,000,000 capitalization) or greater, and a value of zero otherwise. Although the precise significance of $500,000 in capitalization may have changed from 1918 to 1937, a rating of AAA or greater continued to denote a firm with substantial resources, indicated by the fact that *Thomas Register* did not change the dollar figure associated with its AAA rating.

Our use of these firm-specific variables in combination with the shared frailty specification rules out the alternative argument that unobserved firm-specific capabilities explain differential survival chances. Thus, we can focus on how network ties and extra-network firms affect a supplier’s performance.6

RESULTS

Table 1 presents summary statistics and correlations. Table 2 presents results of the failure rate analysis of carburetor and clutch suppliers.

********** Tables 1 and 2 about here **********

We begin by examining the results for carburetor suppliers, for which relationship-specific ties are highly beneficial. Model 1 contains the control variables. Model 2 adds the components of autonomy: constraint from current exchanges, the reduction of constraint due to the availability of extra-network

6 The longitudinal nature of our data would enable us to explore a variety of issues on the dynamic of the network over time, which we do in other work. In the present work, however, we concentrate on the contemporaneous effects relevant to our theoretical focus.
buyers, and the loss of autonomy due to the presence of alternative suppliers. Adding the autonomy variables improves the fit of the model as shown by the incremental log-likelihood chi-squared statistic.

The results support hypotheses 1 to 3. Consistent with hypothesis 1, constraint from current exchanges significantly increases the likelihood that a supplier will fail. Consistent with hypothesis 2 in settings where relationship-specific ties are valuable, the availability of extra-network buyers does not significantly moderate this effect. Finally, the difficulty that buyers face in forming new relationships provides a benefit for carburetor suppliers: as predicted by hypothesis 3, the presence of alternative suppliers does not increase carburetor suppliers’ failure rates.

We next turn to the results for clutch suppliers, for which relationship-specific ties are less beneficial. Model 3 contains the control variables. The addition of the components of autonomy in Model 4 significantly improves the fit of the model.

The clutch results also support hypotheses 1 to 3. Consistent with hypothesis 1, as with carburetor suppliers, the loss of autonomy due to constraint from current exchanges significantly increases the likelihood of a supplier failing. However, unlike the case of carburetor suppliers, the availability of extra-network buyers significantly reduces this effect, consistent with hypothesis 2. Again differing from the case of carburetor suppliers, the presence of other suppliers increases the likelihood that a clutch supplier will fail, consistent with hypothesis 3.

To confirm the implications gained by examining results for each component separately, we used a difference-between-means test (Miner, Amburgey, and Stearns 1990; Wonnacott and Wonnacott 1977:214) to test formally whether the impact of extra-network buyers and extra-network suppliers was greater for clutch suppliers than for carburetor suppliers, as predicted. In both cases, the tests confirmed our hypotheses. As predicted by hypotheses 2, the availability of extra-network buyers reduced the constraint experienced a buyer significantly more for a clutch supplier than a carburetor supplier ($p<.001$, two-tailed test). As predicted by hypotheses 3, the presence of other suppliers increases the likelihood of failure more for clutch suppliers than for carburetor suppliers ($p=.012$, two-tailed test).

These results confirm the contingent effect of extra-network organizations. The finding that constraint from current exchanges increases the likelihood of failure for both carburetors and clutches substantiates hypothesis 1. Because exchanges between clutch suppliers and their customers are not heavily relationship-specific, however, it is relatively easy to form new relationships between a buyer and
supplier. This has two effects. To the benefit of the supplier, it means that the presence of extra-network buyers reduces the impact of constraint from its current exchanges, as hypothesis 2 predicts. However, since buyers also find it easier to work with new suppliers, the presence of extra-network suppliers reduces the autonomy of the supplier, supporting hypothesis 3. Because it is more difficult to form new relationships between carburetor suppliers and their buyers, the presence of extra-network buyers or suppliers has no significant effect on supplier performance, again supporting hypotheses 2 and 3.

********** Figure 1 about here **********

Figure 1 conveys the importance of the contingent effect of extra-network organizations. For carburetor suppliers, which depend on relationship-specific ties, increasing constraint from current buyers increases the probability of failure at the same rate, no matter how many extra-network buyers are available. For clutch suppliers, on the other hand, the impact of increased constraint from current buyers depends on the availability of extra-network buyers. When there are few alternative buyers, increasing constraint increases the likelihood of failure precipitously. In the presence of many extra-network buyers, however, increasing constraint adds only slightly to the likelihood of failure. From an alternative perspective, the absence or presence of extra-network buyers affects clutch suppliers more strongly when they are highly constrained by their current exchanges. By contrast, extra-network buyers have no impact on carburetor suppliers.

Among the control variables, we found that carburetor suppliers that sold only to minor independents were more likely to fail, while this had no effect on clutch suppliers. We interpret this as indicating that differences in capabilities were more important for the more complex carburetors than for the simpler clutches.

DISCUSSION AND IMPLICATIONS

Inter-organizational networks exert a powerful effect on firm performance. Networks exist within a larger population of similar organizations, however, many of which may not be part of an actor’s network. Studies of interfirm relationships have treated these extra-network organizations in contradictory ways. Some studies have ignored extra-network organizations, focusing only on the structure of the actor’s existing network of direct and indirect ties. Other studies have considered extra-network organizations, but found them to have no effect. Still other studies assume that extra-network
organizations consistently moderate the effect of an actor’s network of current ties by serving as potential sources of ties and resources. No theoretical argument has existed for favoring one approach over another.

In this paper, we have shown that none of these approaches is universally applicable. Our central contribution is to elaborate on how networks affect firm performance by considering the contingent effect of extra-network organizations. Specifically, we find that the significance of extra-network organizations varies inversely with the importance of relationship-specific factors of ties.

In the context of buyer-supplier relationships, extra-network organizations are more important when products are simple, technology is stable, there are few interactions among components, information transfer is straightforward and the trading relationship does not require specialized human skills (see Helper 1987). All of these factors contribute to the ability of a buyer or seller to obtain new exchange partners. Suppliers are less constrained by their existing ties, but their buyers are also more easily able to replace them. A supplier’s bargaining position depends not just on its current pattern of exchanges, but on the relative availability of alternative buyers and other suppliers. A supplier’s bargaining power is determined primarily by its current constellation of exchanges for components that are complex, technologically fluid, involve many interactions with other components, pose challenges in information transfer, or require specialized human skills.

This contingency helps resolve the tension between Baker et al (1998) and Burt (1992) that we discussed above. Burt’s study population includes many markets with products that are relatively standardized and stable, including lumber, agriculture, transportation and warehousing, and paper containers. In contrast, Baker et al note that advertising services are complex and customized.

Ignoring this contingency can lead to dramatically underestimating or overestimating the impact of a firm’s network. In essence, one could mistake which panel in Figure 1 accurately portrayed the impact of a firm’s network on its performance. To reflect this, calculations of $O_j$ and $O_i$ (extra-network buyers and extra-network suppliers, respectively) in studies of structural autonomy should account for the nature of the exchange being undertaken into account.

The likelihood of fundamentally misunderstanding a firm’s competitive position is even greater in longitudinal, dynamic studies. As industries evolve, the number of firms usually rises quickly, followed by a shakeout, which leaves a smaller number of surviving firms. This progression may vary in amplitude and timing across buyers and suppliers. The fate of firms in the buyer and supplier population can
dramatically affect a supplier’s competitive position over time, even if none of its customers fail. For example, a manageable level of dependence on a small number of customers can quickly become untenable as outside options vanish over time. Of course, universally assuming this effect would be as misleading as ignoring it.

Our findings generalize beyond buyer-supplier networks. In many studies, the interest is the flow of information, rather than control and bargaining position. For example, network theory suggests that structural holes provide advantages by giving privileged access to information from a diverse set of actors (Ahuja 2000; Burt 1997). However, our findings suggest that they will not always do so. We expect the structure of ties to influence an organization’s performance most strongly when the information of importance in a setting is tacit, fine-grained, proprietary, or holistic, since this type of information benefits most from the relationship-specific aspect of inter-firm ties (Uzzi 1997). To the extent that relevant knowledge is codifiable and non-proprietary, however, it will flow through the population of actors more generally, such that the structure of existing ties will have less influence on the knowledge reaching an actor (see e.g. Miner and Haunschild 1995 on population level learning). The stock of knowledge in a market space or geographical region as a whole might be as or more important than the knowledge held by an actor’s partners.

Our results are also relevant to the literature on structural equivalence, which focuses on the impact of actors that occupy network positions similar to that of the focal firm. Because of different definitions of “similar positions”, this literature is not consistent in how it approaches extra-network actors. The stream of work built on the concept of regular equivalence (Lorrain and White 1971), which (Wasserman and Faust 1994; White and Reitz 1983) defines two actors as equivalent if they have similar ties to actors who are themselves similar. For example, two fathers are equivalent, even if their networks are entirely separate, because they both have ties of parenthood to children. Thus, work using this definition explicitly considers extra-network actors. Work drawing on Burt (1976), Breiger (1975), and others considers actors to be equivalent to the degree that they link to the same actors. In this view, two fathers are not equivalent in the aspect of parenthood, because they relate to different children. This definition effectively ignores extra-network actors because two actors cannot be equivalent if they cannot be linked through a series of network ties (the trivial exception being isolates, who are equivalent by virtue of having no ties).
Studies to date have adopted one definition or the other without developing a theory to explain when one type of equivalence would be more relevant than the other type. Our findings suggest that the latter definition of equivalence—structural equivalence—will be more appropriate to the degree that the presence of relationship-specific factors affects the phenomenon of interest. This may explain Davis’s (1991) surprising finding that firms were no more likely to adopt a poison pill provision when structurally equivalent firms (“regularly equivalent” firms using the language above) had also done so. Davis’s measure was the proportion of firms in the same industry that had adopted a poison pill provision, a measure that encompasses extra-network firms. Davis (1991:593) argues that firms sought detailed and trustworthy information before adopting a poison pill provision, which suggests that a significant finding would have been more likely using a more restrictive definition of equivalence that excluded extra-network firms.

Our findings have important implications for research on networks, whether inter-personal, inter-organizational, or inter-industry. First, researchers must think carefully about the content of the ties in a network. Is a tie valuable for reasons that are relationship specific? If so, attention should concentrate on the existing ties between organizations. To the degree that this is not the case, however, data requirements are more expansive. It becomes necessary to consider firms that are in the study population, even if they are not part of the focal firm’s network. Doing so may require ingenuity in gathering data, since egocentric network studies, which ask informants to identify the elements of their network, will be insufficient by definition.

Taking the appropriate approach to the population of extra-network organizations will be particularly important in three types of cases. The first is when comparing across populations, for example carburetor and clutch suppliers, that differ in the nature of their exchanges or the extent of their extra-network populations. The second is when studying networks over time. While changes in extra-network populations may be obvious, more subtle changes in the nature of the exchanges the actors carry out may also be important. For example, the introduction of technical standards may simplify interactions between buyers and suppliers, increasing the importance of extra-network organizations. Lastly, studies that involve multiplex ties between the same actors, such as advice-seeking, family relationships, and

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7 In a rare paper examining both forms of equivalence, Mizruchi (1993) found that various operationalizations of both were correlated with homogeneous behavior, although the most consistent predictor of similar behavior was common location in central positions of the network.
friendship, must take into account the possibility that the importance of existing ties may vary across types of ties, as may the relevant populations of actors.

Our study also has implications for research design in demographic studies of industries (Carroll and Hannan 2000). In many industries, economic activity consists mainly of business-to-business exchange of goods and services. In such cases, it is preferable to model interdependence among organizations in terms of the structure of relationships among firms in the industry rather than indirect indicators of competition such as the number of firms or industry concentration.

Clearly, research that refines and extends this study would be useful. Possible extensions include assessing whether extra-network actors have differential effects during periods of healthy and adverse industry conditions. It is possible that extra-network actors have less impact during downturns in an industry, when firms may be reluctant to abandon existing exchange partners, making extra-network firms less credible as alternatives. In addition, it would be useful to test the predictions of this paper in terms of other network phenomena such as the diffusion of knowledge or the formation of alliances. We believe that such avenues will provide fruitful venues for continuing work.
APPENDIX: CALCULATION OF AUTONOMY

Burt (1992) proposes that structural autonomy depends on the degree to which a firm is constrained by its buyers and the degree to which its buyers can replace it. In a buyer-supplier network, the degree to which supplier i is constrained by buyer j \((c_{ij})\) depends on the proportion of i’s sales that go to buyer j \((z_{ij})\) and the availability of extra-network buyers \((O_j)\). The relationship is

\[
c_{ij} = (z_{ij})^2 O_j
\]  

(A1)

Lacking data on the dollar amount of a supplier’s sales to each buyer, we set \(z_{ij}\) to one divided by the number of buyers to which supplier i sells in the current year. So that \(O_j\) ranges from near 0 (many extra-network buyers) to 1 (few extra-network buyers), we set it equal to

\[
1 - \frac{\text{Number of extra-network buyers}}{\text{Max(Number of buyers)}}
\]  

(A2)

where \(\text{Max(Number of buyers)}\) is the maximum number of buyers present in any single period in the data—116 buyers in our case. Substituting equation A2 into A1 yields

\[
c_{ij} = (z_{ij})^2 \left(1 - \frac{\text{Number of extra-network buyers}}{\text{Max(Number of buyers)}}\right)
\]  

(A3)

Summing \(c_{ij}\) over all of supplier i’s buyers and distributing the terms in equation A3 yields \(c_i\), the total constraint experienced by supplier i.

\[
c_i = \sum_j (z_{ij})^2 - \sum_j (z_{ij})^2 \left(\frac{\text{Number of extra-network buyers}}{\text{Max(Number of buyers)}}\right)
\]  

(A4)

Introducing coefficients to be estimated yields

\[
c_i = \beta_1 \sum_j (z_{ij})^2 - \beta_2 \sum_j (z_{ij})^2 \left(\frac{\text{Number of extra-network buyers}}{\text{Max(Number of buyers)}}\right)
\]  

(A5)

Simple algebraic manipulation of equation A5 yields the following

\[
c_i = \left(\beta_1 + \beta_2 \left(-\frac{\text{Number of extra-network buyers}}{\text{Max(Number of buyers)}}\right)\right) \sum_j (z_{ij})^2
\]  

(A6)

This equation provides a mathematical statement of our central conceptual concern, the moderating role of extra-network firms on the impact of constraint from current exchanges. \(\sum_j (z_{ij})^2\) measures the constraint imposed on a supplier by its current exchanges, while the term in
parentheses describes the relationship between that constraint and the actual constraint experienced by supplier \(i\). \(\beta_2\) is the key element in that term. It represents the degree to which the availability of extra-network buyers, \(\left(\frac{-Number \ of \ extra-network \ buyers}{Max(Number \ of \ buyers)}\right)\), reduces the impact of constraint from current exchanges on the actual constraint experience by the supplier. Taking the negative of the measure of extra-network ties is an algebraic convenience that allows us to interpret \(\beta_2\) as the reduction in the impact of \(\sum_j (z_{ij})^2\).

A concrete example may clarify the interpretation of our results. Suppose that \(\beta_1\) were estimated to be 7 and \(\beta_2\) were estimated to be 3. Since we use an exponential model of supplier failure, the impact of constraint on the probability of a supplier failing at any point in time (the hazard rate) is

\[
\exp\left(7 + 3\left(\frac{-Number \ of \ extra-network \ buyers}{Max(Number \ of \ buyers)}\right)\right)\sum_j (z_{ij})^2. 
\]

So, when there are no extra-network buyers, the impact of constraint from current exchanges on the hazard rate is

\[
\exp\left(7 - 3(0)\right)\sum_j (z_{ij})^2 = \exp\left(7\sum_j (z_{ij})^2\right) \quad (A7)
\]

When the number of extra-network buyers is at its maximum, however, the impact of constraint from current exchanges on firm failure is reduced by almost half. (Since each supplier has at least one current, i.e., not extra-network, supplier, the ratio of alternative buyers to maximum suppliers will actually asymptotically approach one.)

\[
\exp\left(7 - 3(1)\right)\sum_j (z_{ij})^2 = \exp\left(4\sum_j (z_{ij})^2\right) \quad (A8)
\]

If \(\beta_2\) had not been found to be significantly greater than 0, the impact of constraint from current exchanges on the supplier’s hazard rate would be \(\beta_1\), no matter how many extra-network buyers there were (extra-network buyers would have no moderating effect).

We calculate the other component of autonomy, the availability of alternative buyers \((O_i\) in Burt’s terms), by dividing the number of suppliers in a given year by the maximum number of suppliers present in any single year in out data (18 for clutches, 19 for carburetors). This yields a range from near 0 (low constraint due to few alternative suppliers) to 1 (high constraint due to many alternative suppliers). The interpretation of its impact on supplier failure is as above.
Reference List


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


New York: Norman W. Henley.


# Table 1: Descriptive Statistics And Correlations

**Carburetors (n=205)**

<table>
<thead>
<tr>
<th>Supplier age 0-5 years</th>
<th>Mean</th>
<th>S.D.</th>
<th>Min</th>
<th>Max</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier age 6-10 years</td>
<td>0.22</td>
<td>0.42</td>
<td>0.00</td>
<td>1.00</td>
<td>-0.27</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Supplier age greater than 10 years</td>
<td>0.58</td>
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<td>0.00</td>
<td>1.00</td>
<td>-0.63</td>
<td>-0.58</td>
<td>1.00</td>
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<td></td>
<td></td>
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<tr>
<td>Left-censored supplier (randomized entry date)</td>
<td>0.38</td>
<td>0.49</td>
<td>0.00</td>
<td>1.00</td>
<td>-0.20</td>
<td>0.12</td>
<td>0.08</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplier sold only to minor independents</td>
<td>0.22</td>
<td>0.41</td>
<td>0.00</td>
<td>1.00</td>
<td>0.31</td>
<td>-0.03</td>
<td>-0.24</td>
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<td></td>
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</tr>
<tr>
<td>Large supplier <em>(Thomas Register</em> rating of AAA or better)</td>
<td>0.43</td>
<td>0.50</td>
<td>0.00</td>
<td>1.00</td>
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<td>-0.09</td>
<td>0.11</td>
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<tr>
<td>Total national auto sales/1000</td>
<td>2.60</td>
<td>1.05</td>
<td>0.94</td>
<td>4.46</td>
<td>-0.08</td>
<td>-0.18</td>
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<td>-0.20</td>
<td>-0.15</td>
<td>0.28</td>
<td>1.00</td>
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</tr>
<tr>
<td>H1: Loss of autonomy due to constraint from current exchanges</td>
<td>0.48</td>
<td>0.36</td>
<td>0.02</td>
<td>1.00</td>
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<td>-0.10</td>
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<td>1.00</td>
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<tr>
<td>H3: Loss of autonomy due to presence of extra-network suppliers</td>
<td>0.62</td>
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<td>0.12</td>
<td>-0.20</td>
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<td>-0.38</td>
<td>-0.02</td>
<td>1.00</td>
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<tr>
<td>H2: Reduction in constraint due to extra-network buyers</td>
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<td>-0.99</td>
<td>-0.01</td>
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<td>0.27</td>
<td>-0.72</td>
<td>-0.51</td>
<td>1.00</td>
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</table>

**Clutches (n=130)**

<table>
<thead>
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<th>Supplier age 0-5 years</th>
<th>Mean</th>
<th>S.D.</th>
<th>Min</th>
<th>Max</th>
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<th>2</th>
<th>3</th>
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<th>5</th>
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<th>7</th>
<th>8</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Supplier age 6-10 years</td>
<td>0.29</td>
<td>0.46</td>
<td>0.00</td>
<td>1.00</td>
<td>-0.32</td>
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</tr>
<tr>
<td>Supplier age greater than 10 years</td>
<td>0.51</td>
<td>0.50</td>
<td>0.00</td>
<td>1.00</td>
<td>-0.65</td>
<td>-0.51</td>
<td>1.00</td>
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<tr>
<td>Left-censored supplier (randomized entry date)</td>
<td>0.22</td>
<td>0.42</td>
<td>0.00</td>
<td>1.00</td>
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</tr>
<tr>
<td>Supplier sold only to minor independents</td>
<td>0.68</td>
<td>0.47</td>
<td>0.00</td>
<td>1.00</td>
<td>-0.26</td>
<td>-0.20</td>
<td>0.39</td>
<td>0.20</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large supplier <em>(Thomas Register</em> rating of AAA or better)</td>
<td>0.42</td>
<td>0.50</td>
<td>0.00</td>
<td>1.00</td>
<td>0.07</td>
<td>0.12</td>
<td>-0.15</td>
<td>0.21</td>
<td>-0.22</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total national auto sales/1000</td>
<td>2.59</td>
<td>1.06</td>
<td>0.94</td>
<td>4.46</td>
<td>-0.26</td>
<td>0.13</td>
<td>-0.24</td>
<td>-0.18</td>
<td>0.19</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1: Loss of autonomy due to constraint from current exchanges</td>
<td>0.63</td>
<td>0.41</td>
<td>0.02</td>
<td>1.00</td>
<td>-0.26</td>
<td>0.10</td>
<td>0.29</td>
<td>0.55</td>
<td>0.03</td>
<td>-0.03</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H3: Loss of autonomy due to presence of extra-network suppliers</td>
<td>0.64</td>
<td>0.25</td>
<td>0.21</td>
<td>1.00</td>
<td>-0.13</td>
<td>-0.04</td>
<td>0.15</td>
<td>0.38</td>
<td>0.25</td>
<td>-0.31</td>
<td>-0.24</td>
<td>0.13</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>H2: Reduction in constraint due to extra-network buyers</td>
<td>-0.40</td>
<td>0.34</td>
<td>-1.00</td>
<td>-0.01</td>
<td>-0.03</td>
<td>0.14</td>
<td>-0.08</td>
<td>-0.48</td>
<td>-0.44</td>
<td>0.09</td>
<td>0.26</td>
<td>-0.76</td>
<td>-0.55</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Table 2: Impact of constraint on the supplier failure rate

<table>
<thead>
<tr>
<th></th>
<th>Carburator</th>
<th>Clutch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier age 0-5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplier age 6-10 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplier age greater than 10 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left-censored supplier (randomized entry date)</td>
<td>1.211** 0.667 1.969*** 1.058*</td>
<td>0.0165 (0.1945) (0.0005) (0.0525)</td>
</tr>
<tr>
<td>Supplier sold only to minor independents</td>
<td>2.275*** 1.233** 0.342 -0.679</td>
<td>0.000 (0.0105) (0.2555) (0.1155)</td>
</tr>
<tr>
<td>Large supplier (Thomas Register rating of AAA or better)</td>
<td>-0.204 -0.467 -0.564 -0.303</td>
<td>(0.3685) (0.2415) (0.122) (0.263)</td>
</tr>
<tr>
<td>Total national auto sales/1000</td>
<td>0.355* 0.187 0.270 -0.042</td>
<td>(0.0795) (0.321) (0.132) (0.4375)</td>
</tr>
<tr>
<td>H1: Loss of autonomy due to constraint from current exchanges</td>
<td>6.217***</td>
<td>7.263***</td>
</tr>
<tr>
<td>H2: Reduction in constraint due to availability of extra-network buyers (positive coefficient reduces effect of constraint from current network)</td>
<td>1.916 (0.2005)</td>
<td>3.519** (0.045)</td>
</tr>
<tr>
<td>H3: Loss of autonomy due to presence of extra-network suppliers</td>
<td>3.151 (0.1335)</td>
<td>3.892** (0.0415)</td>
</tr>
<tr>
<td>Dispersion parameter, θ</td>
<td>&lt;.0001 &lt;.0001 &lt;.0001 &lt;.0001</td>
<td>(1.00) (1.00) (1.00) (1.00)</td>
</tr>
<tr>
<td>Observations</td>
<td>205 205 130 130</td>
<td></td>
</tr>
</tbody>
</table>

p-values in parentheses
*** significant at 1%; ** significant at 5%; * significant at 10% (one-tailed tests)

(Piecewise exponential estimation with gamma-distributed shared frailty. Positive coefficient indicates a higher likelihood of failure, with the exception of H2.)
Figure 1: Contingent impact of extra-network buyers on the supplier failure rate

Carburetor supplier
(relationship-specific ties are important)

Clutch supplier
(relationship-specific ties are not important)