Sourcing parts of complex products: evidence on transactions costs, high-powered incentives and ex-post opportunism

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Abstract

This paper revisits evidence on the correlates of sourcing decisions in the US auto industry to see whether adoption of new contracting terms and early involvement of suppliers in design activities (e.g. “relational contracting”) yields different results as compared to previous findings. Previous studies find that US auto firms insource complex parts that require investments in specific assets. Absent large differences in production costs, the results suggest that transactions costs associated with external suppliers exceed transactions costs associated with internal suppliers (e.g. loss of high powered incentives). Using data on 156 sourcing decisions for process tooling (dies) of a new car program we find that under the new relational contracting regime, transaction cost theory continues to have explanatory power for sourcing decisions; however, attributes that favored insourcing in previous studies favor outsourcing in this setting. Moreover, more complex subassemblies are associated with fewer distinct suppliers than expected — evidence of a tendency to co-locate decision rights to reduce transactions costs related to system interactions. After controlling for transaction characteristics that are associated with the sourcing decision, we find no evidence that outsourcing is associated with increased ex post opportunism by the firm (e.g. agreement about contract completion); however, outsourced parts are submitted by suppliers for evaluation significantly later than insourced parts (e.g. delivery holdup). © 2000 Elsevier Science Ltd. All rights reserved.

1. Introduction

With the emergence of hybrid organizational arrangements, the distinction between markets and hierarchies is blurred and the relation between transactions costs (Williamson, 1975) or firm capabilities (Porter, 1980, 1985; Prahalad & Hamel, 1990) and efficient organizational boundaries is clouded. New approaches to monitoring and measurement and “relational contracting” between firms and their suppliers introduce elements of hierarchy to markets; while decentralization and innovations in compensation contracts within the firm introduce market elements to hierarchies (Daft & Lewin, 1993; Zenger & Hesterly, 1997). Previous studies find that, in spite of the loss of “high powered incentives” (profit motives) associated with hierarchies, US auto firms insource complex parts that require investments in specific assets (human and physical capital) (Maston, Meehan & Snyder, 1989; Monteverde & Teece, 1982; Walker & Weber, 1984, 1987). This paper examines the relation between transaction attri-
butes, sourcing decisions and subsequent contract performance after a US auto firm adopts subjective evaluation methods in conjunction with involving suppliers in early design activities (together termed “relational contracting”). These approaches are similar to those of Japanese auto firms, where different relations between transactions attributes and sourcing decisions are observed (Dyer, 1996).

Extensive vertical integration and the arm’s-length nature of transactions with external suppliers that typify US auto firms are a marked contrast to firm boundaries and strategic supply relationships observed in the Japanese auto industry (Cusumano, 1985; Dyer, 1996; Womack, Jones & Roos, 1990). Faced with evidence that Japanese firms develop new vehicles in a fraction of the time, US auto firms have focused on reducing a major component of vehicle development time — the time to develop and build process tooling (dies) associated with metal stampings (Clark & Fujimoto, 1991). Major changes include making die sourcing decisions earlier, so that suppliers are involved in all stages of die development, and modifying the process for evaluating contract completion to emphasize subjective judgement and part interdependencies. These changes resemble the co-specialization of human assets and reliance on trust (as opposed to contract law) that Dyer describes as emblematic of supplier relations in the Japanese auto industry.

In this paper we revisit evidence on the correlates of sourcing decisions in the US auto industry to see whether adoption of new contracting terms and early involvement of suppliers in design activities (e.g. “relational contracting”) yields different results as compared to findings of previous studies. Transactions cost economics might predict that early supplier involvement favors insourcing to avert opportunistic appropriation by the firm of innovation activities (e.g. “stealing” supplier ideas in the development stage) (Walker, 1994). Similarly, subjective evaluation could be predicted to favor insourcing as measures of contract completion become ambiguous (Milgrom & Roberts, 1992). However, studies have shown that decentralized organizations that use relative performance measures to evaluate division managers experience similar problems (e.g. managers haggle over internal transfer prices, Eccles & White, 1988; Poppo, 1995; Vancil, 1978). We examine the association between transaction attributes and sourcing decisions, but make no directional predictions about relational contracting favoring in(out)sourcing because, as Walker and Poppo (1991, p. 66) note, “… how the theory should be used as a predictor of shifts in the current boundaries of the corporation is unclear.”

We use data from a new car program to investigate the relation between 156 sourcing decisions for process tooling (dies) and proxies for contract uncertainty. A unique feature of the database, the physical relation between parts and subassemblies of a single vehicle, is exploited to extend previous studies. Specifically, early studies fail to detect “systems effects” in part sourcing. We test the hypothesis that in addition to part-level characteristics, there are joint contract uncertainties that affect sourcing decisions of parts that are members of a common subassembly. The hypothesis is motivated by the transactions cost literature on interdependencies as well as recent developments in the product development (e.g. Smith & Eppinger, 1997b) and contracting (e.g. Baiman, Fisher & Rajan, 1999) literatures. We find that both part and system characteristics influence the probability of outsourcing. Part and system complexity are significantly related to outsourcing; however, in the opposite direction found in previous studies — the greater the complexity of the part and its subassembly, the greater the likelihood of outsourcing. We also find significant part–system interactions: simple parts that are members of systems with more design constraints are more likely to be outsourced than similar parts in unconstrained systems. After including measures of part and subassembly complexity, there is still evidence that subassembly membership accounts for significant unexplained variation in part-level sourcing — there are systems effects in sourcing. Finally, we provide evidence that more severe uncertainty at the subassembly level is associated with sourcing parts to fewer suppliers than would be expected by chance alone; that is, a tendency to co-locate parts of a subassembly with fewer suppliers. In the extreme, this tendency manifests itself as sole sourcing.
Cynics might argue that although US firms adopt the rhetoric of relational contracting, the proof lies in subsequent incidence of opportunism. Although we do not have access to contract price (or internal cost) data, we investigate two measures that are sensitive to opportunistic behavior. The first measure proxies for opportunistic behavior of the firm and the second proxies for opportunistic behavior of suppliers. We use as a measure of opportunistic holdup of die suppliers, the frequency with which die rework is demanded by the firm as a condition for contract completion. Controlling for die complexity, we find that the incidence of die rework requests is higher for insourced parts than for outsourced parts. Subassembly membership explains variation in the number of rework requests — in short, problems tend to be shared by all members of a subassembly. Outsourced parts that are members of subassemblies with no insourced parts experience a slightly higher incidence of rework requests than outsourced parts in other subassemblies. These results indicate that the firm does not use rework to penalize outsourced parts at the expense of insourced parts. A second measure of opportunistic behavior that we investigate is the incidence of supplier delays in submitting parts for evaluation of contract completion. We find that on average, outsourced parts are submitted 70 days later than insourced parts. In sum, after controlling for transaction characteristics that are associated with the sourcing decision, we find little evidence that outsourcing is associated with increased ex-post opportunism by the firm (e.g. agreement about contract completion); however, it appears that external suppliers engage in delivery holdup. We offer an explanation of these findings from our discussion with managers at the firm and at external suppliers.

Milgrom and Roberts (1992) discuss two important ways in which make-or-buy decisions may violate the theory that firms minimize the sum of production and transaction costs. First, production and transactions costs may not be separable. Second, those making the sourcing decision may not strictly maximize firm value if local (e.g. departmental) objectives conflict with firm goals. This is particularly likely in our research setting since the US auto industry was one of the first modern organizational bureaucracies (Chandler, 1962). We use field research to investigate the degree to which these assumptions are violated in our research setting. We find that both assumptions are problematic; however, all of the studies to which we compare our results use the US auto industry as the research setting and the adoption of relational contracting did not influence intra-firm boundaries in our research site. Thus the absence of strict adherence to firm profit maximization is unlikely to explain differences between our results and previous studies or to explain potentially different decisions being made before and after the adoption of relational contracting. We posit that limitations associated with the assumption of separable production and transaction costs are more likely to explain these differences. Specifically, we argue that previous studies explain long term investments in production capacity, but provide limited insights about part-level sourcing decisions given the existence of capacity. Although we do not have data that would allow us to explore directly changes in sourcing decisions associated with adopting relational contracting, we present an explanation for how relational contracting might alter the relation between production and transaction costs in a manner that could lead to different sourcing decisions.

Section 2 reviews the transactions cost literature on boundaries of the firm with an emphasis on the unique aspects of sourcing complex, new products. Section 3 describes the research setting and variable measures. Section 4 presents the results of empirical tests on the determinants of sourcing decisions. Section 5 compares the incidence of ex-post opportunism for differently sourced dies. Section 6 discusses the results using information gained through field research at the firm and its suppliers. Section 7 concludes with the proposition that strategic supply chain management and the hybrid organizational forms that it portends place new demands on accountants and accounting researchers. First, it is less appropriate than ever for accountants who develop data for sourcing decisions to focus narrowly on production costs. The value chain perspective of strategic cost management with its focus on “costs of ownership” rather than supplier price is essential. Second,
relational contracting and associated performance measures (e.g. supplier ratings) that lend hierarchical characteristics to markets indicate an opportunity to augment our understanding of traditional organizational control systems.

2. Literature overview

2.1. Transactions costs and the boundaries of the firm

In his seminal paper, Coase (1937) identifies transaction costs as the primary determinant of the boundaries of the firm. Ideally, contracts between buyers and sellers provide adaptation strategies for all possible contingencies. However, this requires either certainty regarding the future economic environment or unbounded rational reasoning (knowing all possible future states). Transaction costs arise because complete contracting is often impossible and incomplete contracts give rise to subsequent renegotiations when the balance of power between the transacting parties shifts (Williamson, 1979, 1985). Transaction costs include the costs associated with writing contracts as well as the costs of opportunistic “holdup” at a later date. Although internal organization or “hierarchies” are posited to offer lower costs of coordination and control and to avert subsequent opportunistic behavior, Alchian and Demsetz (1972) and Vancil (1978) discuss related problems of decentralized firms. A major concern is the loss of “high powered incentives” when the pay-for-performance link is attenuated by internal production.

Firms are hypothesized to choose organizational boundaries to minimize the sum of production and transactions costs (Williamson, 1975, 1979). Milgrom and Roberts (1992) identify five attributes of a business exchange that are positively associated with transaction costs: (1) the necessity of investments in durable, specific assets; (2) infrequency of transacting; (3) task complexity and uncertainty; (4) difficulty in measuring task performance; and, (5) interdependencies with other transactions. The necessity of early investments in durable, transactions-specific assets (e.g. human or physical capital) shifts the balance of power between transaction participants, because in later renegotiations these costs are sunk costs of the party that incurs them. Infrequent transactions increase the likelihood of opportunistic behavior in later periods by reducing the threat of retribution. In situations where broader market reputations are at stake, infrequent transactions may be sustainable; however, Klein (1988) points out that even long-term contracts often do not provide sufficient adaptation mechanisms and inflexibility may actually induce holdup. Task complexity, uncertainty and measurement problems exacerbate the problem of identifying and contracting for contingencies. Interdependencies introduce contingencies among transactions that suggest co-location (e.g. system-level sourcing) or that require high level coordination.

The five transaction attributes indicate settings in which opportunistic behavior is likely. If transactions costs offset production cost advantages of the external supplier, the firm subsumes the activity—an outcome termed “vertical integration” or “insourcing.” Empirical research indirectly tests transactions cost theory by relating observed sourcing decisions to transaction attributes that proxy for transactions costs. Evidence on the relation between transactions-specific investments (e.g. Joskow, 1987, 1988; Klein, 1988; Masten, 1984; Masten, Meehan & Snyder, 1989; Monteverde & Teece, 1982; Novak & Eppinger, 1998; Ulset, 1996), contract duration (Crocker & Masten, 1988; Joskow, 1987, 1988), and technological uncertainty (Ulset) generally supports the theory.1

The consistency of the empirical results is startling in light of two problems with the hypothesis that firms take sourcing decisions to minimize the sum of production and transactions costs (Milgrom & Roberts, 1992). First, production and transactions costs are rarely neatly separable. For example, the choice of production technology (and subsequent production costs) is often inextricably linked with production volume, which in turn depends on whether the firm produces some or all products internally. Second, decision-makers are likely to be affected by wealth effects associated with sourcing, and thus are unlikely to take decisions

1 Shelanski and Klein (1995) provide a comprehensive review of empirical research on transaction costs.
that strictly maximize firm profit. Walker and Weber (1994) hypothesize that production and transactions costs differ in “the way that they are mapped onto the decision-making process. (p. 378)”. Because production costs are objectively “calculated” by the accounting system, while transactions costs are assessed subjectively through indirect indicators, “functional managers are likely to differ in the importance that they assign to reducing transaction costs... Consequently, the effect transactions costs have on a make-or-buy choice can partly reflect the influence exerted by the purchasing manager.” They find that production cost differences are more influential in sourcing decisions than transaction cost differences and that experience of the decision-maker is related to assessments of technological uncertainty. Poppo (1995) finds that profit center managers engage in influence activities that increase the costs of price renegotiations above the level that is observed in comparable external market transactions. Whyte (1994) and Roodhooft and Warlop (1999) provide experimental evidence that managers are more reluctant to outsource when investments in specific assets are necessary; and contrary to theory, managers consider previous internal investments in specific assets (e.g. sunk costs) a reason to insource. Finally, studies that focus on cognitive limitations indicate that in certain circumstances decision-makers systematically misestimate (or fail to consider) transaction costs (Dritina, 1994; Lacity, Willcocks & Feeny, 1996).

2.2. The role of transactions costs in sourcing decisions for complex, new products

This paper considers collaborations between producers and suppliers on development of process tooling for new products. Although these collaborations have the potential to make both parties better off, unique difficulties of accounting and contracting for the division of spoils from innovation activities may preclude collaboration. For example, the likelihood of design changes and rework in new product development creates a window for opportunistic behavior and, anticipated by both parties, influences contract terms. Delaying supplier selection until the product design is finalized may reduce recontracting; however, it lengthens product development time and overlooks the fact that development activities are often the only way to discover design flaws (Wheelwright & Clark, 1992). A different approach involves sourcing tools earlier, based on incomplete part specifications and “soft” estimates of the final tool cost, and involving the supplier in development of final specifications (Birou & Fawcett, 1994; Bodog, Deyst, Hoult & Lucas, 1998; Krishnan, Eppinger & Whitney, 1995a, 1995b; Tottie & Lager, 1995; Ward, Liker, Cristiano & Sobek, 1995). Reduced development time may arise as a result of a wider range of novel solutions offered by the supplier or more rapid convergence on the best die design (Bidault, Despres & Butler, 1998; Clark, 1989; Fitzgerald, 1999; Smith & Eppinger, 1997a). These benefits must be weighed against the near certainty of recontracting and associated costs.

When products are assemblies of complex, related components, each potentially sourced from a different supplier, the traditional notion of the firm as a “nexus” of many bilateral supply contracts (Jenson & Meckling, 1976) becomes less appropriate. Suppliers affect and are affected by other suppliers. The firm is one node, albeit central, in a network of interdependent players and a novel form of joint transactions costs must be considered in determining whether parts should be produced by the firm or purchased from external suppliers (Armour & Teece, 1980). Design interdependencies may give rise to central coordination or to “sole sourcing” (Milgrom & Roberts, 1992). Like individual part specifications, part interactions are often uncertain and ill-defined at the time that a sourcing decision is taken (Smith & Eppinger, 1997b). One form of uncertainty is associated

2 An example of an ill-defined, uncertain interaction is “tolerance buildup” between assembled parts (Taguchi, Elsayed & Hsiang, 1989). Tolerance buildup refers to situations in which two randomly selected parts cannot be assembled properly or, when assembled, do not jointly meet design specifications for the assembled product in spite of each part being drawn from a population of parts that are on average at design nominal and within design tolerances. In cases of flexible materials, uncertain tolerance distributions or uncertain covariance among parts, designers typically set individual part tolerances using simple design rules and rely on empirical observation in prototyping to reveal areas that require tolerance revision (Boothroyd, Dewhurst & Knight, 1994).
with assigning fault to a particular part when two or more assembled parts fail to jointly satisfy the firm’s objectives. This interdependency creates a type of opportunistic behavior that may inhibit collaboration with suppliers when part-level interactions are poorly understood — opportunistic shifting of blame for contractual failures among suppliers of interacting parts. The firm may be more motivated to engage in this behavior when one or more parts of a system are insourced; however, one can also imagine this arising if certain external suppliers (e.g. “tier-1” suppliers) are favored or are subject to different transactions costs (e.g. uncertainty is resolved more or less quickly in the course of product development).

Forces that temper the risks of opportunism include the expectation of future transactions between the two parties and the reputational consequences in the broader marketplace to blatant opportunism. As more firms engage in supplier collaborations on new product development, there has been a concomitant increase in the practice of concentrating purchases among a small group of “first tier” suppliers. By forming partnerships with a few key suppliers, firms increase transaction frequency. Although purposeful concentration of power among a few suppliers seems to controvert basic arguments of strategic management [e.g. one of Porter’s (1980) “five forces” of competition is suppliers], Richardson (1993) and Wasti and Liker (1997) describe how Japanese firms rely on parallel sourcing, repeat contracts, shared technological knowledge and reputational consequences to stabilize this seemingly fragile equilibrium. Moreover, it is unclear that decentralized firms that separate innovation activities (e.g. die development) from the use of the innovation (e.g. production facilities) are immune to these problems when bureaucratic inefficiency and shirking are considered.

2.3. Research on sourcing and transactions costs in the US auto industry

Automobiles are complex assemblies of many manufactured parts. A large number of complex, interdependent parts, uncertainty in transactions and the possibility of significant transactions-specific investments, have made auto manufacturing a natural laboratory for testing transactions cost theory. Monteverde and Teece (1982), Walker and Weber (1984, 1987), Masten, et al. (1989), Dyer (1996) and Novak and Eppinger (1998) exploit this setting. Our data do not allow us to perform within-firm comparative analysis of determinants of sourcing decisions before and after the adoption of relational contracting. Consequently, we use these studies as a benchmark for how sourcing decisions were made in the US auto industry before supply chain management strategies were widely considered. This section briefly describes each study.

Monteverde and Teece (1982) examine average sourcing outcomes as judged by an industry professional for 133 categories of parts for two US auto makers in 1976. They find that insourcing is positively related to engineering design effort and the degree to which part designs are firm-specific. There is little evidence that system membership is related to sourcing, and the authors do not investigate whether “sole sourcing,” an extreme solution of co-locating parts that interact, is more likely in the presence of system effects. One explanation of the failure to detect system effects on individual part sourcing decisions is that system membership is defined in relation to assembly sequence and automotive functions (e.g. transmission parts). It is unclear that these are relevant “systems” for sourcing decisions. Masten et al. (1989) extend Monteverde and Teece by demonstrating that investments in transactions-specific human capital

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4 Increased interest in monitoring and measuring supplier performance is a recurring theme in the literature (Ittner & Ponemon, 1992). As outcomes are better defined and performance more easily measured, these measures may be used in enforceable contracts — thereby permitting a broader array of collaborations to fit within traditional market exchanges. Zenger & Hesterly (1997) discuss the use of control mechanisms in markets.

5 The 156 stamped metal parts that we examine are together only one of the 133 categories of parts (termed “body sheet metal”) that Monteverde and Teece (1982) consider. Body sheet metal is one of 37 part categories that comprise the “auto body” system.
(e.g. engineering design efforts) have greater influence on sourcing decisions than investments in transactions-specific physical capital. They do not consider system effects.

Walker and Weber (1984) investigate determinants of 60 sourcing decisions taken within a component division of a large US auto manufacturer over a 3 year period. Factors considered to influence transactions costs were: supplier market competition and uncertainty associated with final product volume and with product design changes. The study is unique in its consideration of the decision-making process. Aside from transactions costs, factors hypothesized to influence the sourcing decision, are buyer experience and comparative production costs between the supplier and the firm. Production cost differences are found to be the strongest predictors of sourcing outcomes with volume uncertainty and supplier market competition having small but significant effects that are consistent with transaction cost theory. Walker and Weber (1987) revisit the results to investigate the possibility that competition in supplier markets moderates the relation between sourcing decisions and transaction costs. When supplier markets are not discriminated, neither type of uncertainty influences sourcing decisions. However, distinguishing high and low competition settings, volume uncertainty is associated with insourcing in low competition markets and product design uncertainty is associated with outsourcing in high competition markets. In both cases, production cost differences are significant predictors of sourcing.

Dyer (1996) compares a sample of 50 supplier–firm relationships for US (3) and Japanese (2) auto firms. Purchasing managers in each firm identified 25 suppliers with whom they worked closely and 25 suppliers with whom they had arms-length relationships. For each supplier–firm pair, survey data was gathered on investments in specific assets, mechanisms employed to guard against opportunistic behavior (e.g. legal contracts, trust, reputation), and information exchange. Consistent with previous studies, US firms use hierarchies when asset specificity is high and arms-length market relations otherwise. Japanese firms make greater use of hybrid governance forms that share characteristics of markets and hierarchies. Dyer concludes that this form yields co-specialization of human assets that results in superior coordination and information sharing between firms without losses associated with hierarchies (e.g. loss of high powered incentives).

Finally, Novak and Eppinger (1998) use the automobile as the unit of analysis and examine the percent of components insourced for 134 luxury vehicles produced by several worldwide auto firms. They find that architectural complexity, a union contract with provisions for in-house component production, and membership of the vehicle in a platform car program that shares parts, are associated with insourcing. They find no evidence of systems effects related to complexity of seven auto systems (e.g. auto body).

In summary, previous studies have consistently found that sourcing decisions in US auto firms conform to the predictions of transactions cost economics. Controlling for differences in production costs between the firm and its suppliers, asset specificity, task complexity and task uncertainty are strong predictors of insourcing. Evidence on the relation between transaction interdependencies and part-level sourcing decisions — so called “systems effects” — is inconclusive. This paper investigates whether adoption by a US firm of relational modes of contracting that are similar to those used by Japanese firms, yields different relations between part and system characteristics that reflect transaction costs and sourcing decisions as compared to these studies.

3. Research setting and variable measures

3.1. Die development and associated transactions costs

Stamped metal parts are made by passing metal “blanks” (e.g. pre-cut metal rectangles) through automated presses that hold “dies.” Dies are molds with upper and lower parts that when forced together, impart shape to metal. Typically several dies are used in sequence to gradually cut, trim and shape the desired part. Dies that produce a single part represent one sourcing decision. All
die sourcing decisions for a vehicle are assumed to occur simultaneously — that is, die development is not sourced in “rounds” with new information potentially becoming available between decisions.

The cost of dies for stamped metal body parts accounts for approximately half of the capital investment for producing a new automobile in existing manufacturing facilities. Die development activities account for the majority of the product development cycle time. All US auto manufacturers have internal die development facilities; however, no firm has enough die shop capacity to perform all of its own die development, repair and maintenance. Agreements with the labor union create conditions that favor using existing die shops to full capacity; however, no die set in our sample was destined for insourcing as a result of union agreements. Similarly, no die set was destined for outsourcing; the internal die shops are capable of producing all dies, had sufficient capacity to produce any die set, and could be asked by the purchasing department to submit cost estimates for any job. Thus we investigate variation in die sourcing, conditional on a certain (unknown) internal capacity utilization for die development.

Although capital investments associated with die development technology are substantial, they are not transaction-specific. Suppliers may have special skills with certain parts (e.g. skill in producing dies for auto doors); however, their competence is not linked to a particular auto manufacturer or vehicle. Unfinished, in-process dies are clearly transactions-specific assets, having no alternative use other than production of parts for which they are designed. However, this is true of all the dies that we examine, so transactions-specific investments are unlikely to explain variation in die sourcing decisions among stamped parts. Similarly, the group of eligible suppliers is roughly constant for all of the sourcing decisions, so we can rule out differences in the intensity of competition in supplier markets as explaining sourcing decisions (Walker & Weber, 1984, 1987).

We turn instead to uncertainty in contracting for dies as the source of transactions costs that influence die sourcing decisions. Although there are several approaches for contracting for die development, the most common, and the one used for all of the parts that we study involves the manufacturer seeking bids for die development on the basis of detailed part specifications and preliminary plans for the dies. Although the firm is buying dies, contract completion is defined by dies that produce parts that conform to design specifications. While preliminary die designs may help the supplier develop an initial price quote, production of the die design is not a condition for contract completion.

Die development is subject to two sources of uncertainty. The first source of uncertainty is associated with estimating the resources required to produce dies that yield parts that meet specifications. Uncertainty in estimating inputs stems from “dimensional bias” — the dimensions of parts produced by a die are rarely the same as those of the die because material flows under pressure are unpredictable. Relating die dimensions and stamping press forces to part dimensions is an art. Dies are produced, tried and reworked to remove dimensional biases (e.g. grinding high spots) in a costly trial and error process.

The second uncertainty in die development is associated with judgement and subjectivity in ascertaining that parts meet specifications. In the past, auto firms considered a die development contract complete when dies consistently produced
parts that conformed to dimensional specifications. However, there is considerable subjectivity in evaluating “consistent performance to specification.” The evidence is typically the dimensional performance of a small sample of parts run on die shop presses. Uncertainty in evaluating the evidence is caused by run-to-run variation, which can result from inconsistencies between die set ups, sheet metal batch-to-batch variation, or changes of critical press settings. Questions of adequate sample size and effects of transferring the dies to the production presses at the firm’s fabrication plant enter into subjective evaluation of whether the dies are satisfactory. Design specifications that are excessively tight and somewhat arbitrary further complicate subjective evaluation (Anderson & Sedatole, 1998). For example, designers may assign a tolerance of plus or minus 1.0 mm as a “rule of thumb” rather than because a larger dimension would compromise part fit or performance or because less dimensional variation would be unnecessarily costly. Similarly, designers may identify a large number of measurement points in an effort to constrain part shape. However, thin metal conforms to its supporting structure, and as a result, different measurements of the same part can differ depending on how the part is supported during measurement. In sum, strict design tolerances for metal parts often increase die development time and cost without producing substantially better or different parts.

3.2. A new approach to supplier relations and contract evaluation

In an effort to reduce vehicle development time, in the 1990s US auto firms began sourcing dies earlier, based on incomplete part specifications, and adopted processes for evaluating contractual performance that incorporated subjective evaluations of whether parts “fit” with other parts (Hammett et al., 1998). These approaches resemble approaches used by Japanese manufacturers. In addition to data on part-level dimensional performance, Japanese firms evaluate “screw bodies” — parts that are screwed or riveted together to form subassemblies that are joined to create the auto body. At an early stage in the die development process, after the dies are capable of producing parts without deformity but before any fine tuning has taken place to achieve specified part tolerances (e.g. mean and variance of part dimensions), parts are assembled. If the assembled parts are jointly satisfactory, the dies are declared complete and purchased at full price even absent the ability to meet individual part specifications. Die development time and cost can be dramatically reduced; however, contract completion for any single part is intertwined with that of other parts in the subassembly. If parts do not pass subassembly evaluation, the supplier is given suggestions for die rework. Fig. 1 depicts the hierarchical configuration of subassemblies that are evaluated. Each circular “node” indicates a subassembly that is evaluated to ascertain contract completion for dies. Hierarchically related nodes (“tiers”) reflect the gradual build-up of the auto-body. First tier subassembly evaluations are targeted for a particular date and occur as soon as all parts are submitted. Higher tier subassembly evaluations have later target dates. If no acceptable subassembly can be created from parts that do not meet specifications, then the default is the old mode of contracting — the supplier must build dies that

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10 Die shops test dies on try out presses that differ from production conditions. Die shops typically do not have a line of presses (or a transfer press) connected by automatic material handling equipment. Rather, they mount the first die of a die set in the tryout press and manually produce the parts. Then they remove the first die, mount the second die and manually perform the second operation on the parts. This continues through the die set until the parts are complete. The alternative of moving the dies to the actual production line for tryout is rarely used because it is too costly to remove a full line of stamping presses from production.

11 Higher tier contracts are not necessarily “held up” by lower tier contracts. Lower tier contracts that are judged in compliance prior to higher tier evaluations generally are not “revisited” under the same contract. If the firm believes that problems diagnosed at a higher tier can be remedied by changes in lower tier parts previously judged to be in compliance, then a second contract for an engineering change would be needed. If the dies have been transferred to the production facility, internal die facilities may perform the rework.
make parts that meet the dimensional specifications.\textsuperscript{12}

3.3. Measurement of variables

The data are product specifications, sourcing decisions, and subsequent evaluations for the die sets of 170 stamped metal body parts for a new car program of a major automobile manufacturer.\textsuperscript{13} Fig. 1 depicts the hierarchical relation between 170 stamped parts of the vehicle and the 32 subassemblies in which they are evaluated.\textsuperscript{14} Numbers in squares indicate parts that first enter each subassembly. Missing part specification data (in parentheses) limits the analysis to 156 sourcing decisions that resulted in 23 external and eight internal die suppliers being awarded die development contracts. In contrast to previous studies, our “systems” reflect terms of the sourcing contract (groups that are evaluated for contract compliance) rather than post-hoc groupings that reflect automobile functions or the sequence of vehicle assembly. We use measures of characteristics of the 156 parts and the 32 subassemblies that they comprise to test the hypothesis that sourcing decisions are jointly influenced by part and subassembly complexity. The data also include information about outcomes of part-level evaluations within the subassembly of which it is first a member, including the date on which parts were submitted by the supplier for evaluation and

\textsuperscript{12} If a product design flaw is discovered, an engineering change is made to the part specification and the firm and supplier negotiate the price of die rework. In interviews with suppliers, it became clear that the likelihood of engineering changes is considered when quoting prices for die development.

\textsuperscript{13} The car is a mid-size, mid-price passenger car that was introduced for the first time during the 1990s. The vehicle was new at the time of the sourcing decisions. It is not a “reskinning” of an existing car line or a “carryover” nameplate. This is important because it limits the degree to which historical relationships between suppliers and the firm may influence specific sourcing decisions. Clearly, however, certain suppliers may be more likely than others to win contracts as a result of historical relations with the firm on different car programs.

\textsuperscript{14} One of the 33 subassemblies depicted in Fig. 1 is strictly evaluated for subassembly fit, with no new parts included; consequently, it is not included in the analysis.
whether the supplier was required to perform die rework. We use this information to construct proxy measures for ex-post opportunism.

The dependent variable for the part-level sourcing analysis, INSOURCE, takes on the value 1 if the dies for the part are built by the auto company and 0 if the dies are built by an external supplier (outsourced). The dependent variable used to investigate factors that contribute to sole sourcing of parts from a particular subassembly is the difference between the actual number of different suppliers and the expected number of different suppliers for a given subassembly. The expected number of suppliers is the number expected when \( N \) suppliers are selected with replacement from a population of 31 internal and external suppliers, where \( N \) is the number of parts in the subassembly. Thus the variable, CONCENTRATION, represents a crude attempt to measure “abnormal” deviation in the total number of suppliers that emerge for a subassembly following the pursuit of any particular sourcing strategy, given the number of parts that comprise the subassembly and the population of suppliers from which to choose. Negative values (using fewer suppliers than expected) suggest an overt strategy to co-locate parts of a subassembly. For the sample of 32 subassemblies, CONCENTRATION takes a value less than zero for 22 subassemblies and ranges from \(-7.50\) to \(+0.18\) with a mean of \(-1.87\) and a standard deviation of \(2.25\). On average, fewer suppliers are used than would be suggested by chance alone.

We use two dependent variables as proxies for the extent of opportunistic behavior by the firm and by suppliers after the contract is awarded. One measure, REWORK, is an integer that indicates the frequency with which subassembly evaluations resulted in the die supplier being asked to perform die rework under terms of the original contract. By demanding rework, the firm increases suppliers’ costs with no recourse for renegotiating the price (unless the rework is in conjunction with an engineering change). A second measure that is controlled by suppliers, DELAY, is the number of days between the date on which parts are requested by the firm to be available for subassembly evaluation and the date that parts are actually submitted. By delaying part submission, the supplier may decrease the firm’s propensity to demand rework or increase the likelihood that another part within the subassembly (produced by a more compliant supplier) is targeted for rework. Table 1 presents descriptive statistics for the dependent and independent variables at both the part and subassembly-level.

Two measures are used to proxy for contract uncertainties in die development:

- **LNCONPNT**: The natural log of the number of dimensional control points on the part design. On part drawings, designers identify critical points where completed parts must be measured to ascertain dimensional performance (e.g. mean and sample variation). Die development contract compliance is judged in part by measuring performance to specification at these critical points. Uncertainty about material flow properties causes designers to select more control points in areas of the part with unusual curvature, in very thin regions and in areas that adjoin other parts, where “fit and finish” are critical. Thus, the number of critical control points is a proxy for part complexity and uncertainties in contracting for die development. A log transform is used because the data are skewed by several parts with a large number of critical points as compared to the remaining sample.

15 The analysis was repeated using a population of 24 suppliers (that is, treating the eight internal suppliers as one), with no qualitative change in the results. The results are also qualitatively similar using a simple dichotomous measure set equal to one for parts with fewer than expected suppliers and zero otherwise.

16 A limitation of our study is that we have no data on unique supplier capabilities or on which suppliers were considered for a given part. Consequently we assume that the population from which the actual supplier was drawn includes all suppliers that eventually received at least one part.

17 A third indicator for whether the part is an outer body panel was considered but found to have no relation to sourcing decisions or subsequent contract outcomes. Consequently, it is not included in the reported results.
The natural logarithm of metal thickness (LNTHICK) for the part. The rigidity of thicker parts makes them easier to measure with precision relative to design specifications and tolerances. As a result, there is less uncertainty in ascertaining whether design specifications have been met. Although it is more difficult to resolve issues of performance relative to design specifications for thin parts, the parts are more easily accepted in a less-than-perfect state. Thin parts are often married to rigid parts in the sub-assembly; consequently part-level imperfections may be offset by systems effects.

Novak and Eppinger (1998) use similar measures in their composite vehicle “body complexity” scale, created by summing the number of: body side outer parts, the number of inner parts, the number of different metal thicknesses for all parts, the number of joints for all parts and the maximum number of die strikes for any part. The engineering literature on metal stamping also supports these proxies for contract
uncertainty (e.g. Hammett et al., 1998; Liu et al., 1996).

We hypothesize that four subassembly-level characteristics influence die sourcing decisions: the number of parts in the subassembly (NUMPARTS); an indicator for whether the subassembly is a member of a second tier or higher subassembly (HI-TIER; see Fig. 1); and two measures of the average part complexity of the subassembly, ALNCONPNT and ALNTHICK. The latter two variables are averages of the part-level characteristics, LNCONPNT and LNTHICK, for the parts in a subassembly (treating lower-tier subassemblies as one “part”). The other variables are described below. Together these four variables proxy for joint transactions costs that arise among interdependent parts.

NUMPARTS: The number of parts first included in a subassembly and the number of lower level subassemblies that are evaluated together for contract compliance (e.g. for a second tier subassembly that is formed by joining two first tier subassemblies and adding four parts, NUMPARTS equals 6). As NUMPARTS increases, there are more opportunities for parts to interact with one another (e.g. more mating surfaces of adjacent parts). The greater the number of adjoining parts, the more likely are part interactions that give rise to joint transactions costs.

HI-TIER: The 32 automobile subassemblies are in a nested, six-level structure. Data limitations preclude modeling the fully nested structure. Nonetheless, uncertainties associated with producing dies for parts in tier-1 subassemblies are different from those associated with parts in tier-2 and higher subassemblies. Tier-2 and higher parts are married to a preexisting subassembly that by virtue of assembly is somewhat rigid. Related to the concepts of part thickness, parts that are added to higher tier subassemblies are easier to evaluate because of the subassembly support structure. Another potential difference between tier-1 and higher tier parts is the information setting. Although it is not necessary, it is possible for dies for tier-1 parts to be judged in contract compliance before tier-2 and higher parts are evaluated. If this occurs, then tier-2 and higher parts are somewhat constrained to fit within the envelope of the tier-1 subassembly. By judging lower tier parts in compliance, the firm limits its freedom to later shift blame for noncompliance to these parts. As an extreme illustration, if all tier-1 parts achieve compliance before tier-2 subassemblies are evaluated, then if noncompliance is observed at tier-2 and there is ambiguity about the cause, only those parts that enter at tier-2 are candidates for blame. While it is true that tier-1 compliance is rarely revisited, higher level evaluations are not detained by lower-level compliance. Nonetheless, evaluations occur in sequence, and thus it is reasonable to hypothesize that first tier subassemblies — for which no prior evaluations exist, are in a different information state than higher tier subassemblies. We use an indicator variable, HI-TIER, to distinguish the 11 upper tier subassemblies.

4. Analysis of sourcing decisions

4.1. Part-level sourcing: model specification

Part-level sourcing is modeled as a binary choice between insourcing dies associated with part $i$, in subassembly $j$, (INSOURCE$_{ij}$=1) or purchasing them (INSOURCE$_{ij}$=0). The logistic distribution links the binary choice to part-level ($X$) and subassembly-level ($Y$) characteristics that proxy for contractual uncertainties. Applying a logistic transformation and incorporating the hypothesized relation between parts and subassemblies, yields a hierarchical generalized linear model that can be estimated (Bryk & Raudenbush, 1992; Goldstein, 1995; Kreft & De Leeuw, 1998).

---

18 Investigations of a three-level nested structure (in Fig. 1, parts in tier-1 and subassemblies and parts in tier-2) revealed no evidence of higher order systems effects on part-level sourcing decisions. Consequently we do not believe this is a serious limitation of this study.
Expressed in terms of the part and subassembly level of analysis, the estimated model is:

\[
\text{Level 1: } \log \left( \frac{P}{1-P} \right)_{ij} = \beta_{0j} + \sum_{k=1} \beta_{kj}X_{kij} + \epsilon_{ij}
\]

for part \(i\) in subassembly \(j\), where \(\epsilon_{ij} \sim N(0, \sigma^2)\) and \(X_k\) are \(k\) part-level characteristics.

\[
\text{Level 2: } \beta_{0j} = \gamma_{00} + \sum_{l=1} \gamma_{0l}Y_{lj} + u_{0j}
\]

\[
\beta_{kj} = \gamma_{k0} + \sum_{l=1} \gamma_{kl}Y_{lj}
\]

for subassembly \(j\), where \(u_{0j} \sim N(0, \tau^2)\) and \(Y_l\) are \(l\) subassembly-level characteristics.

Expressed in combined form, the estimated model is:

\[
\log \left( \frac{P}{1-P} \right)_{ij} = \left( \gamma_{00} + \sum_{l=1} \gamma_{0l}Y_{lj} + u_{0j} \right) + \sum_{k=1} \left( \gamma_{k0} + \sum_{l=1} \gamma_{kl}Y_{lj} \right)X_{kij} + \epsilon_{ij}.
\]

Reorganizing yields an equation with fixed level-1 effects, fixed level-2 effects, fixed interactions between levels, and random effects:

\[
= \left( \gamma_{00} + \sum_{k=1} \gamma_{k0}X_{kij} \right) + \left( \sum_{l=1} \gamma_{0l}Y_{lj} \right)
\]

\[
+ \left( \sum_{k=1} X_{kij} \left( \sum_{l=1} \gamma_{kl}Y_{lj} \right) \right) + (u_{0j} + \epsilon_{ij}).
\]

In accounting research, it is more common to see the second level of the analysis modeled as a fixed effect. For example, the ANCOVA (analysis of covariance) model is a regression model that includes continuous independent variables as well as dummy variables that are used to code group membership. Compared to the level-2 equation above, ANCOVA does not consider factors that explain system effects (e.g. subassembly characteristics) nor does it assume that system effects are measured with error and drawn from a common distribution. Kreft and De Leeuw (1998) compare alternative modeling strategies and discuss conditions under which multilevel modeling is a superior approach. The most important statistical consideration in using the multilevel approach is the presence of intraclass correlation.19 Multilevel modeling addresses limitations of disaggregate (e.g. part-level) modeling brought about by intraclass correlation. Equally important, it does not suffer the inefficiency of aggregate (e.g. vehicle-level) modeling brought about by discarding information about lower level variation. A final consideration in selecting a multilevel modeling approach is whether the researcher is fundamentally interested in explaining both level-1 and level-2 variation. Because theory suggests that both part and systems-level characteristics are associated with transaction costs and sourcing decisions, multilevel modeling is appropriate for this research.

In the following sections, we discuss the results of estimating four increasingly complex hierarchical models of sourcing. The strategy of reporting successively complex models is recommended in the literature on multilevel modeling as a means of ascertaining model stability between levels (Snijders & Bosker, 1999). Evidence of model stability enhances our confidence that the model is properly specified. It is particularly important in the case of nonlinear models because familiar measures of model fit (e.g. likelihood ratio tests and explained variance) that are derived from linear approximations are somewhat suspect.

4.2. A two-level model with a random intercept

Model 1 in Table 2 is the simplest test of interdependence among sourcing decisions of parts with common subassemblies. The model is similar

---

19 Barcikowski (1981) provides evidence on the inflation of the implicit alpha-level for testing coefficients in the presence of intraclass correlation for different group sizes. For a group size of 10 with relatively low intraclass correlation (0.05), the alpha level of 0.05 is inflated to 0.11. For intraclass correlation equal to 0.20, the alpha level is inflated to 0.28. The intraclass correlation of our data is approximately 0.15 and group sizes are typically less than ten parts. Consequently, analysis at the part level could easily result in overstated significance of regression coefficients.
Table 2
The association between part-level sourcing decisions and transactions costs
This table presents results of modeling the relation between part-level sourcing decisions and variables that proxy for contractual
uncertainties in die development. The dependent variable takes on the value one for parts that are sourced internally and zero for
parts that are outsourced. A hierarchical linear modeling approach is employed to allow exploration of interdependencies among
parts that are members of a common subassembly. The data are sourcing decisions and related part descriptions for 156 automotive
stamped metal parts from a single new vehicle. The parts are evaluated for contract compliance based in part on how they perform
when assembled in one of 32 subassemblies; thus we also consider how subassembly characteristics affect sourcing. A general
expression for the logistic, two-level model of insourcing that is estimated is:
Level 1: \[ \log \left( \frac{p}{1-p} \right) = \beta_0 + \sum_{k=1}^{K} \beta_{k1}X_{kij} + \epsilon_{ij} \] for part \( i \) in subassembly \( j \), where \( \epsilon \sim N(0,\sigma^2) \) and \( X_k \) are \( k \) part-level characteristics.
Level 2: \[ \beta_{ij} = \gamma_0 + \sum_{l=1}^{L} \gamma_{l1}Y_{lj} \] for subassembly \( j \), where \( \nu \sim N(0,\tau) \) and \( Y_l \) are \( l \) subassembly-level characteristics.
Expressed in combined form, the estimated model is:
\[ \log \left( \frac{p}{1-p} \right) = \left( \gamma_0 + \sum_{l=1}^{L} \gamma_{l0}Y_l + \nu \right) + \sum_{k=1}^{K} \left( \gamma_{k0} + \sum_{l=1}^{L} \gamma_{kl}Y_l \right)X_{kij} + \epsilon_{ij}. \]
Reorganizing yields an equation with fixed level-1 effects, fixed level-2 effects, fixed interactions between levels and random effects:
\[ = \left( \gamma_0 + \sum_{l=1}^{L} \gamma_{l0}Y_l \right) + \sum_{k=1}^{K} \gamma_{k0}X_{kij} + \sum_{l=1}^{L} \gamma_{kl}Y_lX_{kij} + \nu Y_l + \epsilon_{ij}. \]

Model 1  Model 2  Model 3  Model 4

<table>
<thead>
<tr>
<th>Level 1 fixed effects</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>INTERCEPT ( (\gamma_{00}) )</td>
<td>-0.27</td>
<td>-0.29</td>
<td>-0.25</td>
<td>-0.26</td>
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<tr>
<td>( (0.27) )</td>
<td>( (0.29) )</td>
<td>( (0.37) )</td>
<td>( (0.44) )</td>
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<tr>
<td>LNGTHICK ( (\gamma_{10}) )</td>
<td>( 1.12^{**} )</td>
<td>( 1.17^{**} )</td>
<td>( 2.92^{***} )</td>
<td>( 2.92^{***} )</td>
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<td>( (0.57) )</td>
<td>( (0.58) )</td>
<td>( (1.00) )</td>
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<td>( (0.39) )</td>
<td>( (0.58) )</td>
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<tr>
<td>NUMPARTS ( (\gamma_{01}) )</td>
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<td>( -0.21^{*} )</td>
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<td>( -0.10 )</td>
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<td>( (0.09) )</td>
<td>( (0.10) )</td>
<td>( (0.78) )</td>
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<td>HI-TIER ( (\gamma_{02}) )</td>
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<td>0.17</td>
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<td>( (1.50) )</td>
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<td>ALNTHICK ( (\gamma_{03}) )</td>
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<td>1.31</td>
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<td>( (1.50) )</td>
<td>( (1.28) )</td>
<td>( (1.46) )</td>
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<td>( 0.07 )</td>
<td>( -0.00 )</td>
<td>( -0.00 )</td>
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<table>
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<th>Interactions</th>
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</thead>
<tbody>
<tr>
<td>LNGTHICK * NUMPARTS ( (\gamma_{11}) )</td>
<td>( -0.08 )</td>
<td>( -0.08 )</td>
<td>( -0.08 )</td>
<td>( -0.08 )</td>
</tr>
<tr>
<td>( (0.23) )</td>
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<td>( (0.23) )</td>
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</tr>
<tr>
<td>LNGTHICK * HI-TIER ( (\gamma_{12}) )</td>
<td>( -6.61^{***} )</td>
<td>( -6.61^{***} )</td>
<td>( -6.61^{***} )</td>
<td>( -6.61^{***} )</td>
</tr>
<tr>
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</tr>
<tr>
<td>LNGTHICK * ALNTHICK ( (\gamma_{13}) )</td>
<td>( -0.57 )</td>
<td>( -0.57 )</td>
<td>( -0.57 )</td>
<td>( -0.57 )</td>
</tr>
<tr>
<td>( (3.20) )</td>
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</tr>
<tr>
<td>LNCOMPNT * NUMPARTS ( (\gamma_{21}) )</td>
<td>( -0.20 )</td>
<td>( -0.20 )</td>
<td>( -0.20 )</td>
<td>( -0.20 )</td>
</tr>
<tr>
<td>( (0.15) )</td>
<td>( (0.15) )</td>
<td>( (0.15) )</td>
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</tr>
<tr>
<td>LNCOMPNT * HI-TIER ( (\gamma_{22}) )</td>
<td>1.10</td>
<td>1.10</td>
<td>1.10</td>
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<tr>
<td>( (1.36) )</td>
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<tr>
<td>LNCOMPNT * ALNCOMPNT ( (\gamma_{24}) )</td>
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<td>( -0.67 )</td>
<td>( -0.67 )</td>
<td>( -0.67 )</td>
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<tr>
<td>( (1.56) )</td>
<td>( (1.56) )</td>
<td>( (1.56) )</td>
<td>( (1.56) )</td>
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</tr>
</tbody>
</table>
to the familiar one-way ANOVA model in which the estimated intercept is the “grand mean;” however, the degree to which group (subassembly) means differ from the grand mean is treated as a random effect:

$$\text{INSOURCE}_{ij} = \beta_{0j} + \varepsilon_{ij}$$

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

where $\varepsilon \sim N(0, \sigma^2)$ and $u \sim N(0, \tau^2)$.

The results indicate that while, on average the intercept, $\gamma_{00}$, is not significantly different from zero (translating the log odds back to the probability yields the percent of insourcing in the sample), there is significant subassembly-level variation around zero as indicated by the significant standard deviation of INTERCEPT. This is similar to (unreported) ANOVA results of significant ($F$-statistic of 2.57) between-group variation that accounts for 39% of variation in the data. Knowledge of group membership and the posterior distribution of outcomes allow 75% of part sourcing decisions to be correctly predicted (compared to 60% correctly predicted knowing only the posterior distribution).

4.3. A two-level model with fixed effects and a random intercept

Model 2 in Table 2 introduces variables that proxy for part-level transactions costs, while retaining the simplest form of interdependence in the sourcing decisions of parts from common subassemblies. Each level-1 variable is centered around its subassembly mean, thus the estimated intercept is the grand mean of the log odds of insourcing for parts that are of average complexity in their own subassembly.\(^{20}\) The estimated relation is:

$$\text{INSOURCE}_{ij} = \beta_{0j} + \beta_{1j} \text{LNTHICK}_{ij} + \beta_{2j} \text{LNCONPNT}_{ij} + \varepsilon_{ij}$$

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

where $\varepsilon \sim N(0, \sigma^2)$ and $u \sim N(0, \tau^2)$.

As before, although the intercept, $\gamma_{00}$, is not significantly different from zero, there is significant subassembly-level variation around zero. Part-level variables are significantly related to variation in sourcing decisions within each subassembly. Thicker parts with fewer control points are more likely to be insourced. Stated differently, more complex parts are sourced with external suppliers in spite of transactions costs associated with contract uncertainty. Although part-level variables are significantly associated with sourcing outcomes, an insignificant difference between the approximate likelihood ratio of Model 1 and 2 indicates that Model 2 is not a significant

\(^{20}\) Level 1 variables are centred around the group mean to lend a meaningful interpretation (between versus within-group effects) to coefficients of subsequent models (discussed later). It is retained in this model to enhance comparability across models.

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Table 2 (continued)

<table>
<thead>
<tr>
<th>Random effects</th>
<th>1.09***</th>
<th>1.20***</th>
<th>1.27***</th>
<th>1.53***</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.D. of INTERCEPT ($u_0$)</td>
<td>1.09***</td>
<td>1.20***</td>
<td>1.27***</td>
<td>1.53***</td>
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<tr>
<td>Model fit and improvement statistics</td>
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<td>438.3</td>
<td>438.5</td>
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<tr>
<td>Approximate likelihood ratio ($-2 * \log \text{likelihood}$)</td>
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<td>1.1</td>
<td>0.9</td>
<td>20.9**</td>
</tr>
<tr>
<td>Difference from model 1 likelihood ratio</td>
<td>75.7</td>
<td>66.6</td>
<td>67.3</td>
<td>75.0</td>
</tr>
<tr>
<td>Percent correctly predicted(b)</td>
<td>75.7</td>
<td>66.6</td>
<td>67.3</td>
<td>75.0</td>
</tr>
</tbody>
</table>

\(*, **, ***\)significant with $P$-value $\leq 0.10, 0.05$ and $0.01$ (two-tailed test).

\(a\) Group mean centering level 1 variables in conjunction with including grand mean centered variables in the second level model that are group averages of the level 1 variable (e.g. ALNTHICK) imparts unique meaning to the estimated coefficients. The estimated coefficient for the level 1 independent variable describes variation in sourcing decisions within a level 2 group while the estimated coefficient for the level 2 variable describes the variation between groups. Kreft and De Leeuw (1998) discuss alternatives for variable centering for two-level models.

\(b\) A naı¨ve model, in which only knowledge of the posterior distribution is available, correctly predicts 60% of sourcing decisions.
improvement over Model 1.\textsuperscript{21} Only 67\% of sourcing decisions are correctly classified.

4.4. Means as outcomes model: a two-level model with fixed and random components

Model 3 introduces to Model 2 variables that proxy for contractual uncertainties that arise with subassembly-level interactions among parts. This model is commonly known as a “means as outcomes” model because the level-1 intercept, is modeled as an “outcome” of level-2 explanatory variables. Again, level-1 variables are centered around the group (subassembly) mean. With the exception of the indicator variable, HI-TIER, Level-2 variables are centered around the grand mean. The estimated model is:

\[
\text{INSOURCE}_{ij} = \beta_{0j} + \beta_{1j}\text{LNTHICK}_{ij} + \beta_{2j}\text{LNCONPNT}_{ij} + \epsilon_{ij}
\]

\[
\beta_{0j} = \gamma_{00} + \gamma_{01}\text{NUMPARTS}_{j} + \gamma_{02}\text{HI-TIER}_{j} + \gamma_{03}\text{ALNTHICK}_{j} + \gamma_{04}\text{ALNCONPNT}_{j} + u_{0j}
\]

where \( \epsilon \sim N(0, \sigma^2) \) and \( u \sim N(0, \tau^2) \).

The intercept, \( \gamma_{00} \), is not significantly different from zero; however, there is significant subassembly-level variation around zero. Part-level variables continue to explain variation in sourcing decisions within subassemblies. The number of parts in the subassembly is significantly related to sourcing variation between subassemblies. However, as the significant random component of the intercept indicates, even after including this variable, significant unexplained subassembly-level variation remains. Between-subassembly variation in the mean likelihood of insourcing is not related to HI-TIER, ALNTHICK or ALNCONPNT. Although part and subassembly-level variables are significantly associated with sourcing outcomes, an insignificant (Chi-squared test) difference between the approximate likelihood ratios of Model 1 and 3 indicates that Model 3 is not a significant improvement over Model 1. As in the case of Model 2, only 67\% of sourcing decisions are correctly classified.

4.5. Slopes and means as outcomes model: a two-level interaction model with fixed and random components

Model 4 introduces to Model 3 interactions between part and subassembly characteristics. This “slopes and means as outcomes” model, allows all level-1 coefficients (intercepts and slopes) to be “outcomes” of level-2 explanatory variables; however, only the intercept varies randomly:

\[
\text{INSOURCE}_{ij} = \beta_{0j} + \beta_{1j}\text{LNTHICK}_{ij} + \beta_{2j}\text{LNCONPNT}_{ij} + \epsilon_{ij}
\]

\[
\beta_{0j} = \gamma_{00} + \gamma_{01}\text{NUMPARTS}_{j} + \gamma_{02}\text{HI-TIER}_{j} + \gamma_{03}\text{ALNTHICK}_{j} + \gamma_{04}\text{ALNCONPNT}_{j} + u_{0j}
\]

\[
\beta_{1j} = \gamma_{10} + \gamma_{11}\text{NUMPARTS}_{j} + \gamma_{12}\text{HI-TIER}_{j} + \gamma_{13}\text{ALNTHICK}_{j}
\]

\[
\beta_{2j} = \gamma_{20} + \gamma_{21}\text{NUMPARTS}_{j} + \gamma_{22}\text{HI-TIER}_{j} + \gamma_{24}\text{ALNCONPNT}_{j}
\]

where \( \epsilon \sim N(0, \sigma^2) \) and \( u \sim N(0, \tau^2) \).

The intercept, \( \gamma_{00} \), varies significantly around zero even after including variables that are significantly related to subassembly-level variation. With the exception of LNCONPNT, the part and subassembly level variables previously found to be significant remain so; however, the interpretation of the effect of LNTHICK is augmented with evidence of a significant interaction with HI-TIER. For parts that are of greater than average thickness, there is an increased likelihood of outsourcing if the subassembly is in the second tier or higher of the

\textsuperscript{21} In the multilevel modeling literature, the likelihood ratio is commonly referred to as a “deviance” statistic. For nonlinear models this statistic is derived from a linear approximation. As a result, it is possible for a slightly more complex model to have a higher likelihood ratio of models 2 and 3. This is a general problem of determining model fit for nonlinear models rather than a problem of multilevel models. See Snijders and Bosker (1999) for a complete discussion of model fit for nonlinear, multilevel models.

\textsuperscript{22} Average subassembly thickness but average subassembly control points is hypothesised to influence the coefficient for the marginal influence of part-level thickness on part sourcing. Conversely average subassembly control points but not average part thickness is hypothesised to be related to the marginal effect of part-level control points on part sourcing.
vehicle evaluation sequence. To illustrate, consider a part that is average in every respect except thickness — instead allow a thickness of one standard deviation above the grand mean log thickness (0.43). If this part is a member of a subassembly that is average in every respect and is a first tier subassembly, the probability of insourcing is 0.73 = \[1 + \exp\{-(0.26 + (2.92*0.43))\}\] \(^{-1}\). If the part is a member of a subassembly that is in the second tier or higher of the evaluation sequence, the probability drops to 0.14 = \[1 + \exp\{-(0.26 + (2.92*0.43) + (0.43*1*6.61) + 0.17)\}\] \(^{-1}\). Stated differently, parts that are members of upper tier subassemblies, the evaluations of which are possibly constrained by evaluations of tier-1 subassemblies, are more likely to be outsourced if they are thick. In contrast to previous models, a significant difference between the approximate deviance statistics of Models 1 and 4 indicates that Model 4 is a significant improvement over Model 1. Model 4 correctly classifies 75% of sourcing decisions and does so using information that is readily available to the firm and its suppliers prior to the price quote and the sourcing decision.

4.6. Sole sourcing subassemblies as an extreme solution to systems-related transactions costs

The previous models examine sourcing decisions of individual parts as a function of part and subassembly-level characteristics. In this section we use the identity of suppliers to whom parts are sourced to address the transactions cost hypothesis that severe systems interactions lead to optimal co-location of interacting parts with a limited number of suppliers (either internal or external). Table 3 provides results of estimating the relation between the abnormal number of different suppliers (CONCENTRATION) and subassembly characteristics that reflect part interactions (HI-TIER, NUMPARTS, ALNTHICK, and ALNCONPNT) for the 32 subassemblies. The results indicate that as the number of parts in the subassembly increases, sourcing decisions become more concentrated with a few suppliers. In contrast, for HI-TIER subassemblies, where rework alternatives may be constrained by previous decisions and where joining rigid subassemblies may limit blame-shifting and

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient estimate (standard error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.578 (1.52)</td>
</tr>
<tr>
<td>NUMPARTS</td>
<td>-0.527*** (0.058)</td>
</tr>
<tr>
<td>HI-TIER</td>
<td>0.979** (0.411)</td>
</tr>
<tr>
<td>ALNTHICK</td>
<td>-0.577 (0.773)</td>
</tr>
<tr>
<td>ALNCONPNT</td>
<td>0.319 (0.798)</td>
</tr>
<tr>
<td>Adjusted R(^2)</td>
<td>0.76</td>
</tr>
<tr>
<td>Model F-statistic</td>
<td>25.79 (0.000)</td>
</tr>
</tbody>
</table>

\(\ast\ast\ast\ast\) significant with P-value \(\leq 0.10, 0.05\) and 0.01 (two-tailed test).

\(a\) The results are qualitatively similar when a population of other opportunistic behavior, more suppliers are employed than expected. The average thickness and dimensionality of parts in the subassembly have no effect on sole sourcing tendencies.\(^2\) In sum, there is evidence of a propensity to concentrate parts of complex subassemblies with fewer suppliers.

\(^2\) In unreported results we substitute for the average thickness and number of control points of parts in the subassembly, the minimum thickness and the maximum number of control points (e.g. maximum part-level complexity) for any single part in the subassembly. The coefficients for NUMPARTS and HI-TIER are qualitatively similar, and the coefficient on the natural logarithm of the minimum part thickness is negative and significant at the P\(\leq 0.10\) level (one-tailed test). The results are consistent with the interpretation that concentrating parts with a limited number of suppliers is more likely when part interactions are pronounced.
5. Evidence of ex-post opportunism

The firm appears to outsource complex parts in complex subassemblies and insource simple parts in simple subassemblies — precisely opposite of the pattern observed in earlier studies of sourcing in the US auto industry. Adoption of more relational modes of contracting and functional evaluation of

Table 4
Evidence on ex post opportunism
This table presents results of modeling the relation between two measures of ex post opportunism (REWORK and DELAY) and previous sourcing decisions (OUTSOURCE at the part level and PROPIN at the subassembly level), controlling for part and subassembly complexity. OUTSOURCE is set equal to 1 if the part is outsourced and PROPIN is the proportion of parts that first enter a subassembly that are insourced. Hierarchical linear modeling is used to explore interdependencies among parts (n = 156) that are members of a common subassembly (N = 32). With the exception of the indicator variable, OUTSOURCE, and the control variable, LEADTIME, the level-1 independent variables are group mean centered. With the exception of PROPIN, the level-2 independent variables are grand mean centered.

<table>
<thead>
<tr>
<th>Dependent Variablea</th>
<th>Firm opportunism</th>
<th>Supplier opportunism</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>REWORKb</td>
<td>DELAY</td>
</tr>
<tr>
<td><strong>Level 1 fixed effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERCEPT (γ00)</td>
<td>0.12</td>
<td>−39.60</td>
</tr>
<tr>
<td>(0.39)</td>
<td>(48.81)</td>
<td></td>
</tr>
<tr>
<td>LNTHICK (γ10)</td>
<td>0.12</td>
<td>−68.43**</td>
</tr>
<tr>
<td>(0.46)</td>
<td>(22.71)</td>
<td></td>
</tr>
<tr>
<td>LNCONPNT (γ20)</td>
<td>0.60*</td>
<td>34.40**</td>
</tr>
<tr>
<td>(0.34)</td>
<td>(17.52)</td>
<td></td>
</tr>
<tr>
<td>OUTSOURCE (γ30)</td>
<td>−1.68**</td>
<td>69.44**</td>
</tr>
<tr>
<td>(0.75)</td>
<td>(35.11)</td>
<td></td>
</tr>
<tr>
<td>LNTHICK * OUTSOURCE (γ40)</td>
<td>−0.57</td>
<td>46.90**</td>
</tr>
<tr>
<td>(0.43)</td>
<td>(21.49)</td>
<td></td>
</tr>
<tr>
<td>LNCONPNT * OUTSOURCE (γ50)</td>
<td>0.48</td>
<td>−2.99</td>
</tr>
<tr>
<td>(0.39)</td>
<td>(20.77)</td>
<td></td>
</tr>
<tr>
<td>LEADTIME (γ60) (control)</td>
<td>0.30**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td></td>
</tr>
<tr>
<td><strong>Level 2 fixed effects</strong></td>
<td>1.19*</td>
<td>2.26</td>
</tr>
<tr>
<td>ALNTHICK (γ01)</td>
<td>(0.66)</td>
<td>(35.10)</td>
</tr>
<tr>
<td>ALNCONPNT (γ02)</td>
<td>0.68</td>
<td>73.50**</td>
</tr>
<tr>
<td>(0.61)</td>
<td>(35.72)</td>
<td></td>
</tr>
<tr>
<td>NUMPARTS (γ03)</td>
<td>0.02</td>
<td>−2.79</td>
</tr>
<tr>
<td>(0.04)</td>
<td>(2.32)</td>
<td></td>
</tr>
<tr>
<td>PROPIN (γ04)</td>
<td>−1.19**</td>
<td>−19.11</td>
</tr>
<tr>
<td>(0.57)</td>
<td>(31.57)</td>
<td></td>
</tr>
<tr>
<td><strong>Random effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.D. of INTERCEPT (u0)</td>
<td>0.29</td>
<td>29.19***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>62.27</td>
</tr>
</tbody>
</table>

* ** coefficient is significant with P-value ≤ 0.10, 0.05 and 0.01 (two-tailed test).

a Dependent variable definitions: REWORK, number of times that a supplier was formally asked to perform die rework as a result of subassembly evaluations; DELAY, the number of days between the date that the firm requested part submission for subassembly evaluation and the actual date of part submission by the supplier.

b REWORK, an integer with values between zero and four, is assumed to have a Poisson distribution. Results are qualitatively similar using a logistic function to represent the probability of any incidence of rework. The population average model is reported.
parts within subassemblies seems to be associated with a different relation between sourcing and transactions costs. An obvious question is whether after controlling for characteristics that influence sourcing, outsourced parts subsequently experience greater incidence of opportunistic behavior than insourced parts. In Table 4 we investigate this using two measures that are sensitive to opportunistic behavior.

5.1. Opportunistic demands for die rework

The first column of Table 4 examines one manifestation of opportunistic behavior by the firm — whether parts from outsourced dies fail subassembly evaluation more often, with requirements that the supplier perform die rework as a condition for completing the contract. Controlling for complexity that makes rework likely regardless of the source, we estimate the relation between the incidence of rework requests (REWORK) and die sourcing for the part (OUTSOURCE) and its subassembly (PROPIN). As in the sourcing analysis, we consider the possibility that part-level rework requests are influenced by rework decisions for parts of the same subassembly. The intuition, again, is that there are multiple ways of bringing nonconforming subassemblies into conformance. After sourcing decisions are made, the firm may be motivated to impose rework on external suppliers rather than internal suppliers if they can do so under the terms of the original contract. If this behavior is common, then the coefficient on PROPIN should be positively related to rework.

We use hierarchical linear modeling for a Poisson distributed variable because REWORK is a positive integer. Measures of part complexity are group mean centered and measures of average subassembly complexity are grand mean centered; thus the coefficients on the level-1 variables represent within group effects while the coefficients on the level-2 variables represent between group effects. The indicator variable, OUTSOURCE is not centered and takes on the value of one for outsourced parts. The uncentered level-2 variable, PROPIN, is the proportion of parts that first enter the subassembly that are insourced. At the part level we switch from an indicator of insourcing to an indicator of outsourcing to enhance interpretation of the results about the marginal effects of outsourcing on rework for an average part (subassembly unspecified):

- \( \gamma_{00} + (\gamma_{04}(0.47)) \) is the log of the incidence of rework for insourced parts of average complexity in average subassemblies. The estimated incidence of rework is 0.64.
- \( (\gamma_{00} + (\gamma_{04}(0.47) + \gamma_{30}) \) is the log of the incidence of rework for outsourced parts of average complexity in average subassemblies. The estimated incidence of rework is 0.12.
- \( (\gamma_{00} + \gamma_{30}) \) is the log of the incidence of rework for outsourced parts of average complexity in subassemblies with no insourced parts. The estimated incidence of rework is 0.21.

A comparison of the first two points indicates that the firm is not using its right to demand rework to penalize external suppliers. Rather, after controlling for part and subassembly complexity, insourced parts are more likely to require die rework than outsourced parts. A comparison of the last two points indicates that the firm is not exploiting the opportunity to shift blame for subassembly failure from internally to externally sourced dies. We find a significant between-group effect in REWORK that is related to the average part complexity of the subassembly and the proportion of insourced parts. These systems effects support the hypothesis that problems observed in subassembly evaluation tend to create die rework for all members of the subassembly. After including the level-2 explanatory variables for the random intercept, the remaining unexplained variation is not significantly different from zero.

5.2. Opportunistic delays in submitting parts for evaluation

The second column of Table 4 examines the number of days between the date when the part is requested by the firm to be ready for subassembly evaluation and the date when parts are provided by the supplier to the firm for evaluation
(DELAY). Although it is a linear rather than a Poisson model, the included variables are similar to the previous model for REWORK. We introduce the variable, LEADTIME, which is the number of days between completion of part designs and the requested part submission date, to control for submission delays that stem from delays that may be primarily the responsibility of the firm. As before, variable centering lends specific interpretations to the coefficients about the marginal effects of outsourcing on submission delays for an average part in an average subassembly:

- $\gamma_{00} + (\gamma_{60} \times 473.65) + (\gamma_{04} \times 0.47)$ is the number of days that an insourced part of average complexity in an average subassembly is delayed. The estimated delay is 93.5 days.
- $\gamma_{00} + (\gamma_{60} \times 473.65) + (\gamma_{04} \times 0.47) + \gamma_{30}$ is the number of days that an outsourced part of average complexity in an average subassembly is delayed. The estimated delay is 163.0 days.
- $\gamma_{00} + (\gamma_{60} \times 473.65) + \gamma_{30}$ is the number of days that an outsourced part of average complexity in a subassembly with no insourced parts is delayed. The estimated delay is 171.9 days.

After controlling for part complexity and subassembly membership, for average parts in average subassemblies external suppliers delay submission for evaluation by 70 days as compared to internal suppliers. As expected, the marginal effect of part thickness (e.g. reduced complexity) is to reduce delay time; however, external suppliers do not take full advantage of producing an easier part, submitting these parts later than internal suppliers. So, for example, evaluated at one standard deviation above the grand mean thickness, insourced parts are delayed 64 days (as opposed to 93.5 days) while outsourced parts are delayed 154 days (as opposed to 163 days). There is significant variation in submission delay between subassemblies; however, variation is unrelated to the sourcing status of other parts in the subassembly. We observe a significant between-group effect in DELAY that is related to the average part complexity in the subassembly but is unrelated to the sourcing of parts. These systems effects are consistent with the hypothesis that problems observed in subassembly evaluation tend to be shared among members of the subassembly. After including the level-2 explanatory variables for the random intercept, there remains significant unexplained variation between subassemblies.

6. Field investigation of results

In light of findings that differ substantially from previous studies, we conducted interviews with managers, cost estimators, and design engineers from the firm and die suppliers to try to understand our results. Two assumptions that Milgrom and Roberts (1992) characterize as fundamental weaknesses of transactions costs theory — inseparable production and transaction costs and wealth effects for decision-makers — appear to be problematic in our research setting. As we describe below, inseparable production and transactions costs, are more likely to explain differences between our results and previous studies, since wealth effects are likely to be common to studies of the US auto industry. Similarly, inseparable costs are more likely than wealth effects to be associated with shifts in sourcing decisions following the adoption of relational contracting because organizational boundaries within the firm were not altered in conjunction with the adoption of relational contracting. Our data do not permit us to corroborate changes in the pattern of sourcing decisions as a function of part and subassembly characteristics before and after adoption of relational contracting. Nonetheless, as we describe below, it seems likely that the nature of the contractual changes altered the nature of production and transaction cost interactions by increasing the variance associated with die making inputs.

Our interviews revealed that sourcing decisions are more aptly described as short term optimization of capacity utilization, given the level of die build capacity. The decision about firm boundaries (that empirical transactions cost studies examine) was taken earlier, when long term decisions about die-build capacity were taken. Importantly, decisions about long-run capacity investment and short-run
utilization are influenced by an important internal use of die-build capacity — die maintenance and repair. Once dies are in production, the cost of die repair becomes trivial when compared to the opportunity cost of idle presses. Consequently, the appropriate level and use of new die-build capacity depends on repair and maintenance demands that old dies create. In the extreme, new die-build activities could be fully outsourced not because transactions costs are inconsequential, but because, in the short run, the opportunity cost of using internal assets for die-build rather than die maintenance is exceedingly high. Internal sourcing may be a strategic choice to maintain capability in die development, but it is also a secondary use of excess capacity in die development assets. In this setting, the long term strategic decision is whether to invest in internal production capability and if so, at what level. The (relatively) short term part-level sourcing decision becomes, which parts to produce in the die build capacity that remains after accommodating die repair and maintenance demands. Sourcing decisions are an attempt to “smooth” utilization of these assets. An explanation that is consistent with our results is that constant utilization is attained by insourcing dies that are associated with low uncertainty about resource demands — those with lower than average transactions costs. Consider further the possibility that the new approach of involving suppliers earlier and permitting acceptance of dies that would previously have been termed “nonconforming,” reduces the expected cost of production (to the supplier) but almost certainly increases the variance of production costs. If so, this presents a situation in which the adoption of relational contracting could cause parts that would previously have been insourced to be outsourced. These observations are consistent with economic theory, which would consider alternative uses of assets in a make versus buy analysis. However, they are inconsistent with empirical research on transactions costs in the auto industry, which relies on the supplier and the producer having roughly similar production costs to hypothesize that different sourcing decisions reflect the influence of transactions costs.

The matter of the decision-making process for make versus buy decisions is complex. Transactions cost theory assumes that the sourcing decision is made by someone seeking to maximize the value of the firm using complete information about production costs and alternative uses of assets. In our firm the internal die development shops are members of a different operating division from the purchasing organization that makes sourcing decisions and the manufacturing organization that “buys” dies from internal or external die shops. Although the firm has taken steps to enhance communications and align incentives between all three groups, interviews indicate that sourcing decisions are more appropriately described as selection by a decision-maker with local objectives of an internal or an external supplier. Self-interested internal and external suppliers provide data to influence the decision, and the decision-maker has limited opportunities to verify suppliers’ claims about production costs. While concerns about wealth effects associated with sourcing decisions are substantial, it is unlikely that differences in wealth effects explain differing results on the effect of transactions costs on sourcing decisions between our study and those that preceded us because of the common, largely stable industry setting. It is also unlikely that wealth effects changed significantly in conjunction with adoption of relational contracting because (for better or worse) decision rights over the sourcing decision and organizational boundaries were not changed as part of the new contracting approach.

Asked why he was given the most complex jobs, the President of one external supplier remarked, “internal die shops don’t want to do the hard jobs because they don’t want to be on the hook if they can’t make the parts. And the [firm’s] engineers don’t want them to get the work because they don’t think they’ll be responsive [to rework requests].” The implication is that internal die shops submit high cost estimates for complex dies to minimize their exposure to the perceived risk of poor performance. Asked about findings that insourced parts are more likely to face demands for rework while outsourced parts are submitted later for evaluation, the manager explained the

24 The designers of the parts that the dies must produce are in yet a fourth division.
results as evidence that suppliers do not fully trust the firm. He claimed that, anticipating that their parts are likely to be blamed for problems, external suppliers do more work to perfect the dies (relative to part-level specifications) than internal suppliers — resulting in “better” parts (lower rework) but taking longer to achieve (longer submission delays). Of course the data are also consistent with suppliers simply holding the dies longer as a means of altering the likelihood of being required to do rework. In general, managers at the firm agreed that externally produced dies are being “over-worked” relative to internal dies and relative to their preferences. However they acknowledge suppliers’ fear of “punitive” rework requests and hope to counter it over time with behavior to the contrary.

In summary, as uncertainty in die development has increased with earlier involvement of suppliers and more subjective, interdependent evaluations of contract completion, it appears that incremental costs associated with the loss of high-powered incentives are greater than incremental transactions costs. Moreover, although we find no evidence that the firm behaves opportunistically during subassembly evaluations, this may be a premature conclusion. It is possible that, fearing opportunistic behavior, external suppliers submit parts from dies that are more developed than those of internal suppliers. If so, it is unclear whether external suppliers would be subject to more demands for rework than internal suppliers if they did not make these investments in die development.

These observations are not startling to accounting researchers who are accustomed to thinking about organizations as decentralized groups that are populated with self-interested people. However, since these organizational aspects of the make versus buy decision are contemplated, it is difficult to interpret the empirical literature in economics as evidence that transactions costs are a leading determinant of sourcing decisions. In modeling average sourcing behavior for broad classes of auto parts (e.g. Masten et al., 1989; Monteverde & Teece, 1982), early studies focus on determinants of whether any internal production capability exists rather than on part sourcing decisions, conditional on the existence of internal capability. There is little recognition that in the short run a firm may outsource activities in which it has an absolute cost advantage to free resources for activities in which it has a greater relative cost advantage. Related to this, in testing whether insourcing is positively associated with transactions costs, previous research relies heavily on transactions costs favoring insourcing and “understates the costs of managing interunit relationships within the organization (Walker & Poppo, 1991).” Together these limitations are symptomatic of simplifying assumptions common in the empirical literature. Field research implicates problems with these assumptions as one explanation for why we observe different sourcing decisions from those of previous studies when we consider a setting that uses more relational modes of contracting.

7. Conclusion

Economists often explain manufacturing firms’ decisions about whether to make or buy parts as the low cost solution, considering both production and transactions costs. Management accounting texts urge managers to consider “qualitative factors” associated with the reliability and permanence of suppliers’ prices in reaching sourcing decisions. In this paper, we revisit data on the relation between proxies for transactions costs and sourcing decisions in the US auto industry using data from a firm that has started involving suppliers in design activities and has adopted subjective, interdependent evaluations of contract completion. The results indicate that under the new contracting regime, factors that previous studies found to favor insourcing now favor outsourcing. Specifically, complex parts are more likely to be outsourced, as are parts that are members of more complex, interdependent subassemblies. We also find that systems interactions among parts are associated with fewer suppliers being selected than would be expected by chance alone — consistent with the hypothesis that sole sourcing mitigates transactions costs associated with systems uncertainties.
In spite of results that differ significantly from previous studies, we find no evidence that the firm demands rework more frequently for outsourced parts as compared to insourced parts. Moreover, although incidence of opportunistic behavior covaries with subassembly membership, there is no evidence that “problems” are disproportionately attributed to outsourced parts when the subassembly contains at least one insourced part. We find that suppliers are more likely to delay submission of parts for evaluation as compared to internal suppliers. An explanation that emerged from our field research is that, skeptical about the new subjective evaluation methods, suppliers do more work on the dies than internal suppliers and more than the firm prefers. A second explanation is that delays reflect “delivery hold ups” intended to alter the firms’ propensity to demand rework. The data do not permit us to discriminate between these explanations which have very different implications for improving the new contracting approach.

The transactions costs literature and our study have implications for practicing accountants and accounting researchers. Accountants are often called upon to assess whether it is more economical for manufacturing firms to make or buy parts in light of alternative uses of production assets. Management accounting textbooks (e.g. Atkinson, Banker, Kaplan & Young, 1997, pp. 364–8) typically focus on the difficulty of correctly identifying avoidable production costs and comparing them with external suppliers’ prices. Strategic supply chain management and the hybrid organizational forms that it portends place new demands on accountants. Accounting texts mention more difficult to assess “qualitative factors” that influence the reliability and permanence of supplier prices (p. 367). Our research indicates that it is less appropriate than ever for accountants charged with developing data for sourcing decisions to focus narrowly on production costs. The value chain perspective of strategic cost management with its focus on “costs of ownership” rather than supplier price is essential, and we can not assume that “costs of ownership” are minimized with internal production. In short, estimates of uncertainty associated with the reliability and permanence of prices are relevant for both internal and external suppliers. Further, relational contracting and associated performance measures (e.g. supplier ratings) that lend hierarchical characteristics to markets suggest a need to augment our understanding of organizational control systems.

Although our research site provides a unique organizational perspective on sourcing that is absent from some previous studies, it is not without limitations. The empirical analysis requires several assumptions. First, we do not have data on sourcing decisions before and after the adoption of relational contracting. Rather, we must rely on a large body of existing research to proxy for sourcing outcomes prior to the change in contracting. Although the industry setting is common across all of the studies, we must be cautious about overstating the comparability of the studies. A second limitation is that in the absence of data on the date of the sourcing decisions, we assume that sourcing decisions for all die sets are made simultaneously. Thus, there is no time dimension to the decision process that would allow different states of information to influence different sourcing decisions. If sourcing is conducted in “rounds” our analysis would incorrectly ignore covariance between early and late decisions. A second stronger assumption is that sourcing is related only to the characteristics of the part that the dies must produce and its subassembly. In truth, sourcing is almost certainly influenced by historical supplier performance. This limitation speaks to covariance over time between the die sourcing decisions for the vehicle that we study and all prior die sourcing decisions. Future research could address this issue with data on sourcing decisions within and across vehicle development projects. Finally, although our interactions with the firm indicates that product design and system architecture decisions precede die sourcing decisions — indeed product design and process design are governed by different organizations in the firm — it is possible that product designers anticipate sourcing decisions in their product designs (e.g. Novak & Eppinger, 1998). Similarly, it is possible that product designers anticipate die design concerns. Although we think that our results reflect causal relations between
part and system complexity and subsequent die sourcing decisions, we can not rule out the possibility of a more complex, simultaneous optimization of product and process design and sourcing.

In spite of the limitations, this paper differs in several important ways from previous studies. First, rather than study all components of the automobile, we focus on tools (dies) that produce the metal stampings for the auto body. An attractive feature of studying dies is that the sourcing decisions are taken in consideration of a common group of eligible suppliers who use comparable die build technology and are subject to similar production and transactions costs. Focusing on sourcing decisions for dies alone also permits us to develop measures of transactions costs that are tailored to the specific supply setting. For example, we use many of the measures of part complexity that Novak and Eppinger (1998) consider. However, we are not forced to adopt ad-hoc methods of summarizing the data to create a scale for complexity of stamped body parts that can be combined with aggregate scales of complexity in other part systems (e.g. the auto transmission) for a measure of vehicle part complexity. Previous studies have attributed variation in sourcing outcomes across broad categories of parts to transactions-specific investments. We focus instead on within-category variation.

A second strength is analyzing data from actual sourcing decisions associated with a real automobile. With the exception of Walker and Weber (1984, 1987) and Novak and Eppinger (1998), previous studies examine average part sourcing decisions of one or two firms over all vehicles produced for a period of time. Focusing on a single new automobile provides us a large number of sourcing decisions that were made at approximately the same time and subject to the same environmental uncertainties and organizational sourcing strategies. It also allows us to exploit the firm’s structure of subassembly evaluations rather than relying on crude part groupings [e.g. Monterverde and Teece (1982) treat all stamped body parts as a single part and arbitrarily group it with paint, safety belts and automotive glass because together these are assembled to create the “body” of the automobile]. Using a grouping structure that mirrors that of the supply contract allows us to make stronger claims that the systems effects that we estimate are in fact those that influence the sourcing decision.

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