DISCUSSION PAPER SERIES

DP13750

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INDUSTRIAL ORGANIZATION

ISSN 0265-8003

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Discussion Paper DP13750
Published 22 May 2019
Submitted 21 May 2019

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Abstract

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JEL Classification: D86, L14, L62, O34

Keywords: Relational Contracts, hold-up, Buyer-Supplier Contracts, bargaining power

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Acknowledgements
We acknowledge the generous hospitality of Studienzentrum Gerzensee, where substantive parts of the research work were completed. We greatly benefited from comments by seminar participants at Berlin, Bologna, Cambridge, Columbia, Copenhagen, Edinburgh, ESSET (Gerzensee), Frankfurt (CEPR Workshop on Incentives and Organizations), Hebrew (CEPR IO-conference), Helsinki, IIOC Chicago, Mannheim, Madrid-CUNEF workshop, Northwestern, Tel Aviv, Tsinghua Universities, Tor Vergata (Rome), and Warwick. We also benefitted from comments and discussions with James Best, Maria Bigoni, Volodymyr Bilotkach, Patrick

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Trust, Investment and Competition:

Theory and Evidence from German Car Manufacturers*

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1 Introduction

Relational contracts, that is informal arrangements that are not enforced by court action, are an important ingredient in almost all meaningful social and economic interactions, and in business transactions alike. Many, if not all of these arrangements are based on some form of trust, reflecting the belief that the partners in the interaction do not behave opportunistically, and incorporate the future consequences of their action into their current decisions. Such beliefs are central to the implementation of relational contracts in business relationships involving repeated sequences of exchanges. If a party trusts that she will be treated properly by her trading partner, she will be more willing to invest in the relationship, and thereby increase surplus and efficiency.

An interesting example of a trust-based relationship involving one buyer and several suppliers is the procurement of parts for the production of complex products, such as automobiles, high-speed trains, or aircraft. One should expect that buyers and suppliers especially in these industries respond to the complexity of the exchanged parts by drafting detailed contracts with clauses that are verifiable in court. Yet buyer-supplier interactions in the German and Japanese automobile industry are based on detailed contracts that rely for their enforcement in large part on purely trust-based relationships.[1] And this occurs in spite of the fact that, in sharp contrast to the U.S. industry, suppliers undertake the majority of the innovative R&D investment embodied in any new car model.

Investigating these relationships in Germany in the 2000's is particularly interesting because of a disruption initiated by Ignacio Lopez, a key procurement manager in both the U.S. and the European automotive industries. In 1993 Lopez was poached away by VW from GM as chief procurer with the express mission to implement confrontational arm's-length procurement to extract rents from upstream suppliers towards restoring VW's profitability. His innovation essentially consisted of expropriating the suppliers' intellectual property rights (IPRs hereafter) embodied in a blueprint, by using them without compensation to procure worldwide for production.[2] Driven by the same quest for higher short run profitability, some other, but not all, automotive producers followed suit and adopted aggressive procurement strategies in the late 90's and the early 2000's, which caused considerable turbulence in industry relations.

The long shadow of this turbulence prompted the board of the German Association of Automotive Manufacturers, that includes the CEOs of all German automotive companies and of key suppliers, to commission a comprehensive benchmarking study to evaluate in detail the interaction between suppliers and manufacturers. The study centered around the trust relationship, its variation across buyer-supplier pairs, and the consequences of this variation. The top corporate executives observed the execution phase and strongly encouraged individual respondents to participate and to respond truthfully. The cen-

[1] A clear evidence of this is the small number of court cases involving car manufacturers and suppliers.

[2] See Moffett and Youngdahl (1999) for a detailed description of Lopez's innovation in procurement strategy (and the ensuing legal fight between GM and VW). For a discussion of Lopez's long shadow over Opel, a German daughter company of GM, see *here* while a collection of articles on Lopez's case is found *here*.

tral results were presented to those in charge of sales and sourcing, and discussed in detail. The empirical analysis of this paper is based on this benchmarking evidence, that benefited from the industry expertise in defining concepts and understanding the underlying structure of complex procurement relationships. Thus, our evidence reflects and clarifies an important historical episode involving intra-industry variation in trust across buyer-supplier relationships.

Our first empirical finding is that higher trust levels are associated with less frequent part failure resulting, by a commonly accepted interpretation, from buyer-specific suppliers' investments. While since Williamson (1979) path breaking work, this association appears in line with theoretical research when it comes to the procurement of complex products, this is *not* so in our case. The association is significant *only* in the procurement of low-tech parts, and not in that of high-tech parts. This is our first, rather surprising, empirical finding.

Our second empirical finding strikes us as equally surprising. While one might expect that more competition among suppliers is detrimental to the trust relationship with a given buyer, we find that, on the contrary, higher levels of relationship-specific trust are associated with *tougher* competition. Specifically, a higher level of trust within a long-term relational contract is associated with more suppliers invited by the buyer to compete in the development of a part for a new car model, and with more frequent co-sourcing in the production of that part. Again, we observe this relationship only for low-tech, and not for high-tech parts.

Thus, we reveal puzzling empirical aspects of a supply relationship that do not necessarily find an explanation in the existing theory. We therefore develop our preferred explanation of these findings within a model of relationship-specific investment in a relational contracting setting, that reflects the environment from which we have gathered the empirical evidence. The model explains how trust matters for supplier's investment and competition among suppliers, and also characterizes the environments in which trust matters and those in which it does not.

In this model, a buyer repeatedly procures a product. This involves the development of a blueprint requiring buyer-specific and non-contractible R&D investment on the part of the supplier(s), followed by the production phase. Several firms are capable of developing such a blueprint and producing the part. These potential suppliers differ in production costs, that are unknown to the buyer. At the start of the development phase, the partner in the relationship who has the bargaining power chooses the amount of desired investment. Then a subset of the suppliers is invited to invest in R&D and to competitively develop a blueprint for the part in question, and one of these blueprints is selected. One or more suppliers are then awarded the production contract, possibly through a competitive auction.

We focus on relational contracts featuring two key non-contractible components. The first component is the buyer's promise to select suppliers for production *only* from the set of suppliers invited to develop the blueprint rather than from outside that set. The second component is the participating supplier's investment towards the blueprint. A deviation by the buyer consists of opening competition for the production contract to all potential suppliers independently of whether they undertook any development investment. A deviation by a supplier consists of insufficient investment into developing a blueprint compared to the level promised in the relational contract. Upon observing this, the buyer can punish the deviator by excluding him from future procurement. Conversely, suppliers can punish the deviating buyer by reducing R&D investment in future blueprints. In equilibrium the partner in the relationship who has the bargaining power identifies the optimal relational contract by maximizing his/her expected payoff and ensuring incentive compatibility, that is ensuring that neither party in the relationship has an incentive to deviate from the equilibrium strategies of the infinitely repeated interaction, thus inducing future cooperation.

If the market power resides with the buyer, she will restrict herself to selecting for development and production a strict subset of suppliers from the total set, and since this implies higher investment but also higher procurement costs, she does so up to the point in which incentive compatibility of the suppliers binds. The expected rents generated from eventual production compensate for the non-contractible investment. We identify a sufficient condition under which slack in this incentive constraint induced by an increase in trust—that is, an increase in the participants' belief that the future involves a cooperative arrangement—allows the buyer to increase both the investment by the typical supplier and the intensity of competition, that is the number of suppliers invited to participate in the development of the product and in the procurement contest. In this situation, the decrease in future rents due to increased competition is compensated for by the higher valuation of future interactions due to increased trust.

For this to be true it is critical that the buyer limits competition for the production contract to those suppliers that in the past participated in the development of the product and undertook the required relationship-specific investment. It is this restricted access to competition for the production contract that prevents suppliers from reacting to increased competition at the development stage by reducing their future relationship-specific investment. This incentive effect disappears if, in line with Lopez's strategy, competition for the production contract is opened to all suppliers, including those that had not undertaken relationship-specific investments.

The structure and these results is reflected well in our data for interactions involving low-tech parts. We obtain the empirical results involving high-tech parts when we change the identity of the market leader. Indeed for technologically complex parts the leading supplier(s) have considerable bargaining power.[3]

If the market power resides with the leading supplier(s), the typical supplier restricts himself to invest, and will capture all rents up to the point in which the buyer's incentive constraint binds. This difference in the binding incentive constraint with respect to the case where the buyer has the bargaining power delivers identifiably different effects of a change in the level of trust. The empirical finding that for high-tech parts the relationship between trust and the quality of investment fades allows us to conclude that for high-tech parts the market power necessarily resides with the supplier. Otherwise the supplier's incentive compatibility constraint would be binding, implying a positive relationship between the level of trust and the quality of the supplier's investment which

[3]This is typically linked to specific technologies involving proprietary IPRs observed in the data.

we do not observe in the data. Allowing for the possibility that the bargaining power could reside with either of the trading partners in the relationship is a central aspect of our theoretical analysis.

Our study reflects the specifics of a country and of an important sector. Yet it also provides insights that are clearly valid in many other procurement environments involving complex parts for complex products. Key examples are parts for the production of aircraft and trains, as well as defence and aerospace procurement.[4]

The remainder of the paper is organized as follows. In Section 2 we review the pertinent theoretical, experimental and empirical literatures. In Section 3 we introduce our data, derive the two central empirical relationships and discuss causality and robustness checks. In Section 4 we develop our preferred explanation of these relationships within our theoretical model. Section 5 concludes. Details involving the collection and the description of our data, as well as the proofs of our propositions, are relegated to the Empirical and Theoretical Appendices, respectively.

2 Related literature

Many authors have looked at the automotive industry as one of the most interesting, if not a generic, example of vertical relationships. Grossman and Hart (1986), Milgrom and Roberts (1992), Taylor and Wiggins (1997) and Holmström and Roberts (1998), among many others, use as examples the classic Fisher-GM case or Asanuma (1989)'s case-based description of upstream supplier-buyer relationships in the Japanese automotive industry. Malcomson (2012) uses the same case to motivate his survey of the relational contracting literature. Our evidence is in the same spirit. But rather than based on cases, it is based on arguably the largest and most detailed benchmarking study to date.

Central to this study was the concept of trust in a relationship. Any business relationship that does not resort to legal means of enforcement would, in colloquial terms, be referred to as based on trust. "In a relational contract, one party trusts the other when the value from future trade is greater than the one period gain from defection" (MacLeod, 2007, p. 609). In this sense, trust can be seen as the basis for relational contracts. The notion is already highlighted in Macauley (1963), Klein and Leffler (1981), and MacLeod and Malcomson (1989), and appears also in more recent contributions to the literature on relational contracting where the discount factor is regarded as the best indicator of trust.[5] Kvaloy and Olsen (2009) in their model of relational contracts with endogenous verification, argue that the discount factor is indeed a good indicator of trust in a relationship, and perform comparative statics on the latter to understand how their results change when different levels of trust are present.[6] In our relational

[4]See Gilson, Sabel, and Scott (2010) for other interesting examples of procurement relationships involving the combination of unverifiable innovation and verifiable production components.

[5]See MacLeod (2007) and Malcomson (2012) for summaries of this literature.

[6]Bodoh-Creed (2019) defines trust as the belief that a party has in the opponent's ability to resist the temptation to cheat in a relational contract parameterized by her discount factor. Kartal (2018) defines the discount factor of the principal as a proxy for his trustworthiness, and studies how belief in the principal's discount factor, that is trust, evolves along the relationship.

contracting model, we follow the same approach and interpret the discount factor as an indicator of the level of trust.[7]

Trust interpreted in this way is a key component of an economic decision that does not encompass the multi-faceted sociological and psychological constructs that can also be associated with the term. Malcomson (2012) provides a discussion of this concept and alternative views. While we agree with Williamson (1993) that there are good reasons to use such a view in more general contexts, an interpretation linked to economic incentives seems the most relevant when looking at industrial procurement contracts justifying its use in the survey questions and throughout this paper. Indeed, given that our interpretation of trust is likely to be mostly relevant in business interactions, our empirical analysis only indirectly relates to the many experiments involving the trust game, or to the numerous previous empirical studies of trust and its effects on choices and outcomes in organizations and countries.[8]

For what concerns the theoretical relationship between relational contracts and competition, our model is closest to Calzolari and Spagnolo (2009) where the optimal relational contracting model of Levin (2003) is extended to the case of multiple competing agents, and to De Chiara (2018) where the framework is extended to pre-contractual investment.[9] Calzolari and Spagnolo (2009) highlight a trade-off between reputational forces and collusion: restricting competition to a smaller set of agents helps limiting post-contractual moral hazard, but at the risk of inducing collusion among these agents against the principal. De Chiara (2018) shows that restricting competition/negotiating with a single supplier may also be optimal to sustain pre-contractual investment. None of these models though truly fit the relationships we observe, nor do they study the comparative statics relevant to our data, the robustness to multiple sourcing, and how these change with alternative allocations of the bargaining power among parties.

The only other empirical analysis of the relationship between trust and competition we are aware of is by Francois, Fujiwara, and van Ypersele (2012). Building on a conceptual model of shirking in the labor market, they use, among other data, the World Value Survey to show that more competition between firms is associated with higher levels of trust. In both our empirical analysis and our theoretical model, we demonstrate the reverse causality in our environment of car manufacturing and relying on industry specific measures of trust. It is the presence of high trust in the relationship that allows the buyer to enhance competition among suppliers.

Our paper is also closely related to the literature on incomplete contracts, Grossman and Hart (1986), Hart and Moore (1988), Hart and Moore (1990) and Hart and Moore (2007), and in particular to the analysis of the role that competition plays in an incomplete contract setting. Two aspects relate our findings to that literature. First,

[7] This view is nicely summarized in Cabral (2005), p.6.

[8] An overview of the experimental and neuro-economic literature on the subject is provided by Fehr (2009). For the empirical studies of trust, see La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1997), Guiso, Sapienza, and Zingales (2008), Guiso, Sapienza, and Zingales (2009), Aghion, Algan, Cahuc, and Shleifer (2010) and Sapienza, Toldra, and Zingales (2013).

[9] Board (2011), and Andrews and Barron (2016) also model relational contracts in procurement relationships, but focus on the optimal dynamics of these contracts rather than on competition.

the trade-off between competition and trust we derive in our model is similar in spirit to the mechanism through which competition can reduce inefficiencies associated with the hold-up problem (Rajan and Zingales, 1998; Cole, Mailath, and Postlewaite, 2001a,b; Peters and Siow, 2002; Peters, 2007; Felli and Roberts, 2016). Second, as in our model, the role of the distribution of the bargaining power between the parties in the relationship is highlighted in determining the existence and the extent of the under-investment associated with incomplete contracts and relationship specific investment.

The literature on relational contracts has focused on the negative effect of competition on trust-based relationships.[10] For example, McMillan and Woodrooff (1999) show empirically that a supplier and a buyer can rely more on non contractible dimensions (such as implicit trade credit) when the buyer has reduced access to alternative and competing suppliers. More recently, Macchiavello and Morjaria (2019) study the effects of competition between coffee mills in Rwanda on the prevalence of relational contracts with coffee farmers. They find evidence that an exogenous variation in (downstream) competition between mills reduces the incidence of relational contracting and leads to an inefficient utilization of resources. In our industry setting, the typical buyer uses established relationships to induce upstream competition among suppliers, and she can afford more intense competition when trust is higher, without risking the disruption documented in Macchiavello and Morjaria (2019).

Our analysis is also related to the growing literature on managerial practices in manufacturing firms, and in particular to that relying on relational contracts.[11] Gibbons and Henderson (2012a,b) are the first to suggest a number of reasons why effective relational contracts may be hard to build (or re-build); this may explain why the German manufacturing association was so worried about the turmoil caused by Lopez's procurement strategy in buyer-supplier relations.

Within this literature, Aral, Bakos, and Brynjolfsson (2017) analyze theoretically and empirically how firms source IT hardware and services in different countries. If suppliers' relationship-specific investment increases, the number of suppliers decreases, and firms engage in more repeated relationships with those suppliers. This is consistent with our analysis, for a given level of trust. Our data on bilateral relationships, including our empirical measure of trust, allow us to assess directly the interaction between trust, competition and investment.

3 Trust, investment and competition: evidence

In the aftermath of the confrontational procurement practices implemented by some automotive producers, the industry was concerned that a crisis of trust had adversely affected supplier-buyer relationships. The detailed benchmarking study commissioned by the board of the German Association of Automotive Manufacturers (VDA) to assess

[10]Indeed, in Malcomson (2012)'s comprehensive survey of relational contracting, most papers involve bilateral contracting issues and the few involving multilateral ones address cooperative, rather than competitive, relationships. See also Sako (1992), MacDuffie and Helper (1997), and references therein.

[11]See the surveys by Bloom, Lemos, Sadun, Scur, and Van Reenen (2014) and Gibbons and Henderson (2012b) on management practices, and by Gil and Zanarone (2018) on relational contracts.

the state of supplier-buyer interactions among its members thus focused on the trust relationship of these parties and its consequences. The benchmarking exercise was backed by the chief executives of all German automotive manufacturers and the leading suppliers of automotive parts and was carried out between Fall of 2007 and Summer of 2008 in the form of a detailed questionnaire study. The top management of all firms involved committed to coordinate, and monitor the participation of all individual respondents.[12]

The study involved a collaborative effort at the industry association level, supervised by a steering committee composed of chief procurement and sales executives nominated by the CEOs sitting on the VDA 's board. The steering committee actively participated in the design of the questionnaire and in the phrasing of the key items. This ensured a common understanding of definitions, which is crucial to our identification strategy. All firms addressed by the survey had committed to participate via their representatives in the VDA's board; this contributed to rather complete reporting.[13] Due to its involvement in the design of the study, each firm was fully aware that data collection and reporting would be completely anonymous.[14]

3.1 Data base and sample

The participants and primary addressees of the benchmarking study included all 10 German automotive producers (7 producers of passenger cars and 3 truck makers), and a selected set of 13 major German parts suppliers—all represented in the VDA's board. The survey respondents were high-ranking employees selected by the boards of the participating firms. The respondents of the participating suppliers were asked to evaluate in detail their relationship to each individual buyer (all German automotive producers plus a foreign firm included as a reference party), conditional on supplying parts of one of the different product groups to that buyer at the time of the survey. Benchmarking required that responses related to individual parts could be compared across firms supplying different products belonging to the same product group. To ensure this, we relied on industry standard product group definitions, sorting parts into four different categories, as follows:

Commodities: physically small and technologically unsophisticated;

(High-tech) Components: physically small but technologically sophisticated, often including a combination of mechanical and electronic functionalities;

[12]The questionnaire survey was preceded by case studies carried out between November 2005 and May 2006 that involved numerous interviews with high ranking representatives of first-tier suppliers' R&D, production and marketing departments, and automotive producers' procurement departments. Müller, Stahl, and Wachtler (2016) summarise the results of these case studies. They document in detail the relationship between producers and their first-tier suppliers.

[13]Key results of the exercise were presented in anonymised form to the heads of procurement and sales at the participating firms, providing a further verification of the approach used and of the chosen definitions and questionnaire items by industry experts.

[14]This requirement also prohibits us from providing information in this paper that could identify individual firms' responses or profiles.

Modules: physically large but technologically unsophisticated, such as assemblages of commodities;

(High-tech) Systems: physically large and technologically sophisticated, such as assemblages of components.

We include dummy variables for the types of products in all our specifications to ensure that we are only comparing parts which are considered comparable according to industry practice. In our sample, the share of systems (16.4%) is somewhat below modules (22.4%) and high-tech components (24.3%). Commodities (33.2%) are observed most often. The R&D cost share of parts, which illustrates and underlines the differences between product groups, is significantly and substantially higher for components and systems (around 7.5%) than for commodities and modules (around 5.0%), but not statistically distinguishable within these groups. To control for technological sophistication, we use a high-tech dummy variable, which takes a value of 1 for systems and components.

Towards obtaining a comprehensive picture of buyer-supplier relationships by part categories, we merged our benchmarking data with a separate commercial database, "Who supplies whom" (WSW) collected by supplierbusiness.com. Based on reports by industry participants, this database records actual supply relationships between manufacturers and suppliers at the level of individual parts. In merging the data, we obtained information on the number of different suppliers in actual supply relationships for given parts categories in the German market (for any customer) at the time of the exercise. In Table 13 in the Empirical Appendix we list the names of the individual products by product type together with the number of suppliers engaged by the buyers in our sample, as well as the overall number of suppliers of these parts relevant to the German market. We use the latter number as a proxy for the size of the set of potential suppliers for a given part.

An observation is defined as a given supplier's view on a given buyer's procurement practices with respect to a given part, for example spark plugs. The supplier's view on that buyer's procurement practice with respect to, for example, an electronic stabilization program would constitute a different observation. Different sets of questions were addressed to the corresponding specialists in the firms.[15] Individual respondents answered only questions in their expertise related to part and buyer. We merged these answers from a supplier on a given buyer and part across the different functions to obtain a complete observation. Whenever parts of questionnaires overlapped, we used the arithmetic mean of the responses. Thus, an observation in our empirical approach represents the aggregate view of the supplier's employees that were asked to fill the questionnaire on the relationship with a given buyer involving a specific product within

[15]Respondents were first asked to indicate their function within the company out of the following seven: *pre-development*, *vehicle development*, *series production*, *quality control*, *sales*, *logistics*, and *aftermarket production*. For each part and customer, they would then answer the set of questions suited to their function within the company. See Müller, Stahl, and Wachtler (2016) for a detailed description of the individual functions and the automobile development and production process.

one of the four product classes.[16]

The full questionnaire, containing 185 questions and 150 sub-questions, covers three distinct development phases that any part supplied to automotive producers undergoes: Buyer and model-unspecific *pre-development*, buyer and model-specific *development*, and *series production*. Pre-development is the earliest stage and covers basic R&D on new technology, often purely based on the supplier's initiative, and thus involving mainly a non-specific investment.[17] By contrast, the development phase is model- and therefore buyer-specific. In many cases, the buyer formulates performance requirements for the part in question, but potentially complex interfaces with other parts often under simultaneous development necessitate that these cannot be fully specified. The outcome of the development stage is a blueprint enabling any competent supplier to produce the part. Finally, in series production, one or more suppliers work with the blueprint for the part chosen by the buyer, investing in (expensive) model-specific production tools. Only at this stage parties are able to more specifically—but still incompletely—formalise the product specifications and services to be exchanged. In spite of the cross-sectional nature of our data, observing responses on the pre-development and the development of the currently supplied part allows us to consider longitudinal aspects in our analysis.

The fact that individual questions could be skipped has implications on the choice of sample for regression analysis. We choose to be as conservative as possible. Since the main contribution of the paper is the connection between trust, investment and competition, for each individual regression we require all observations to include answers to these three items, ensuring that there are no sample-composition effects across our central regressions of interest.[18]

Overall, the supplier sample tends towards large participants, with average revenues in 2007 of 9.4 billion euros (stdev. 12.4). Even the smallest participant posted revenues of more than 700 million euros. This is reflected in the self-reported European market shares for the individual products in our sample, with an average share of more than 25% of the European market. Supplier-buyer relationships were long term involving several decades; this ensures that we can talk about repeated relationships.[19]

[16] With regard to survey participation, at the supplier/buyer/product group level, there are theoretically 13 (suppliers) x 11 (buyers) x 4 (product groups) = 572 potential relationships. In fact, out of the 13 suppliers, only 6 actually sell products from each product group, with 3 firms limited to 3 types of products, 4 firms limited to 2 types of products, and 1 firm only selling 1 type of product. Furthermore, since not every supplier provides parts from each product group to each buyer, the potential number of relationships is further reduced to 369. Out of these, we obtained responses for 308 different relationships. The number of complete observations is finally reduced because respondents did not necessarily answer all questions. It is encouraging to see that we obtained sharp results in spite of the potential noise introduced by different respondents to the same observation.

[17] Take the design of a new brake technology. Engineers may have no knowledge as yet of how fast or heavy the car model is in which this brake-system will be implemented.

[18] As robustness checks, we also ran each regression for all available observations. The results overall remain qualitatively unchanged and tend, given the higher number of observations, to be more significant.

[19] Among the observed buyer-supplier relationships in our sample, 61% have lasted longer than 15 years. Among the remaining shorter relationships, the average duration is 8.7 years. Given the annual facelift or introduction of new car models by each automotive producer, this still covers at least 8

3.2 A measure of trust

Key to our analysis is how we measure relationship-specific trust between suppliers and buyers in the German automotive industry. Recall that the typical supplier answered questions specific not only to a particular buyer, but also specific to a defined part for which the individual respondent was responsible. For each phase of the part's life-cycle (pre-development, development, production and sales), the questionnaire included the following request: *Please evaluate the importance of mutual trust between the supplier and automotive producer for the automotive producer's supplier selection*, on a six point scale from 1 (no relevance) to 6 (very important). The request was connected to similar evaluations, for example of the importance of price. Our main quantitative measure of trust is the typical supplier's mean response within each phase of a specific part's life-cycle. We refer to the resulting variable as the "trust index".[20]

To clearly delineate the content of this measure, we look at factors which should influence trust in a relationship. Conceptually, we consider trust in a counterpart to be captured by a belief in the counterpart's type. Higher trust is therefore associated with a lower probability of opportunistic behavior, or, equivalently, more importance being placed on the value of future repeated interactions.[21] One might question whether our measure captures these concepts. A key issue could be that the "importance" of trust would reflect more a characteristic of the part in question than of the relationship. Intuitively, more complex parts requiring know-how might place a higher importance on the issue of relational trust. The distribution of our trust measure across the different types of parts rules this interpretation out. The means for the four types systems (4.82, std. dev. 0.79), modules (4.83, std. dev. 0.71), components (4.89, std. dev. 0.72) and commodities (4.80. std. dev. 0.87) are almost identical and cannot be statistically distinguished.

In addition we would require our trust measure to vary with observed buyer behavior. As to the pre-development and the development phases, respondents were asked to assess *(a)* the frequency of conflicts with the buyer with regard to the supplier's IPR's, as well as *(b)* how often these were leaked in the past by the buyer to competing suppliers. As to the series production phase, respondents were asked *(c)* the frequency of price renegotiations in form of rebates requested in the past by the buyer. The responses to these questions should negatively affect a suitable trust measure. Respondents were also asked to assess *(d)* to which extent an automotive producer helped in unexpected development cost overruns. This can be interpreted as the buyer's investment in the future relationship, which should be positively associated with a suitable trust measure.

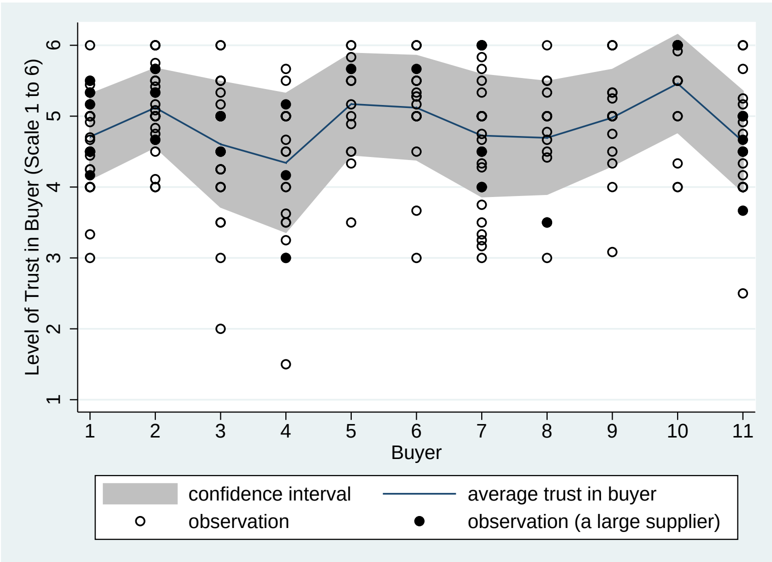
generations of car models. Only 1% of our part-specific observations stated a duration of the relationship of less than 4 years.

[20]Two further trust questions were developed covering more specific topics (and directed at subsets of respondents, only): *What is the importance of trust for your firm's decision to initialize a pre-development with the OEM?* and *How do you evaluate mutual trust between OEM and supplier with respect to honoring each other's intellectual property rights?* Both are highly correlated (0.43, p-value 0.000; 0.47, p-value 0.000) with the trust index.

[21]This notion is very much akin to the notion as introduced by Gambetta (1988) and endorsed by Williamson (1993). For a more recent definition, see Cabral (2005)

We regressed our proposed trust measure onto each of these indicators, controlling for the product type, the supplier's size (measured by 2007 revenues) and the number of competitors for the type in question. The first column of Table 10 in the Empirical Appendix shows the results. "Lopez" opportunistic behavior in the past has a significant, strong and negative effect on our current trust index, as we require. To the contrary, sharing in the development risks by the OEM has a significant positive effect on the trust measure. These observations make us confident that the trust index does, in fact, measure what we are interested in.[22]

Finally, we briefly discuss the observed variation in the trust measure across buyers as summarized in Figure 1. While, much to our surprise, the trust measure in the aggregate varies only insignificantly across buyers, it varies substantially for each buyer, that is within the supply relationships observed for the typical buyer. The example of a given large supplier (black dots) further shows that, even for a given supplier-buyer pair, trust may vary substantially across the individual part types supplied in this relationship: The typical buyer's procurement officers are individually responsible for specific parts, or part groups, and variation in buyer behavior can be expected across parts even towards a given supplier, reflecting in particular the intensity of supply-side competition.



Assessments of the importance of trust in the part-specific buyer-supplier relationship from the supplier's perspective. Assessments by a large supplier in solid black dots. Confidence interval of suppliers' assessments in gray.

Figure 1: Variation in the trust measure.

[22]A further benefit of the measure is that the survey adjacently also asks about the importance of other factors, especially price. As a central robustness check, we normalize the trust index by taking the difference between the importance of trust and price.

3.3 Trust and investment

The first empirical relationship we observe is that higher levels of trust are associated with more relationship-specific investment by suppliers, or equivalently higher part quality. It is well known that measuring relationship-specific investment poses challenges. In our survey, we also do not observe investment directly. Instead, we observe an outcome variable that is strongly related to investment, namely the part-specific failure rate.[23] The underlying logic is the following. After controlling for factors such as part type (more complex parts are more often associated with failures), market factors (external competition could conceivably drive acceptable failure rates down), supplier size (which may be associated with resources and capabilities) and the identity of the buyer (who may, for example, be engaged in complementary investments), the remaining variation in observed part failures should be strongly associated with the supplier's effort and investment.

To measure the occurrence of quality issues, the suppliers were asked: *With respect to the part considered, how often do quality problems occur?*, measured on a 5-point scale, with 1 identifying the lowest and 5 the highest frequency, and the middle of the scale anchored at 50%. The points on the scale are therefore interpreted as probabilities increasing from 0 to 100% in steps of 25%. Our basic specification takes the following form:

$$y_{ijs} = \beta * x_{ijs} + \gamma * Z_{ijs} + \kappa + \alpha_j + \epsilon_{ijs}, \tag{1}$$

where y_{ijs} is the probability that quality problems arise for part i supplied to buyer j by supplier s, x_{ijs} is the trust measure related to supplying part type i to buyer j by supplier s, Z_{ijs} are control variables, κ is a constant, and α_j a buyer fixed-effect. As motivated above, the control variables include dummies for the part type, the supplier's revenues in 2007 as a measure of size, as well as the number of external competitors in Germany, N, derived from the WSW database, as an indicator for the supplier's bargaining power. We estimate two sets of models, standard OLS as a reference, as well as a fractional probit model taking the non-linear nature of the dependent variable into account. Here, as in all following specifications, we estimate robust standard errors that are clustered at the level of buyer-seller pairs.

Our data give us a handle on an issue on which it is usually very hard to gain any traction. When trying to empirically assess under-investment-related quality issues, difficulties typically arise as (a) observed failure rates often cannot be linked to individual parts, (b) it is generally not observable whether quality problems are diagnosed and solved before the parts are installed, and (c) the diligence or skill of the buyer in assembling the final product also affects quality. The advantage of our approach and data is that responses are part-specific, so issue (a) can be easily addressed. The phrasing of the question addresses issue (b), as it included all phases involving the part in question.

[23]It is a standard interpretation of quality-related effort in the literature that supplier investment affects the failure rates of parts (Taylor and Wiggins, 1997; Womack, Jones, and Roos, 1991). Self-reporting of problems may lead to under-reporting—even under anonymity as guaranteed in the study. We would *underestimate* the observed effect if more trust would lead to a higher likelihood of admitting problems in the questionnaire.

Issue (c), the possible complementary effort or skill on the part of buyers, is addressed by introducing a dummy for each of the eleven buyers in our regressions, that captures the buyer's effect on quality.

	Frequency of Quality Problems					
Variables	**OLS**			**Fract. Probit**		
	(1)	(2)	(3)	(4)	(5)	(6)
trust index	**-.035****	**-.040****	-	**-.035****	**-.043*****	-
	(.040)	(.018)		(.021)	(.007)	
trust index (high-tech)	-	-	-.020	-	-	-.028
			(.581)			(.384)
trust index (low-tech)	-	-	**-.049****	-	-	**-.050*****
			(.016)			(.005)
supplier revenues (bln)	-.001	-.002	-.001	-.001	-.001	-.001
	(.430)	(.349)	(.418)	(.419)	(.315)	(.380)
# suppliers overall	.001	.001	.001	.001	.001	.001
	(.318)	(.326)	(.330)	(.328)	(.319)	(.318)
product type						
system (D)	reference category					
module (D)	-.007	-.010	.132	-.028	-.033	.083
	(.919)	(.889)	(.597)	(.736)	(.688)	(.693)
component (D)	**-.149****	**-.156****	**-.154****	**-.165****	**-.176****	**-.145*****
	(.028)	(.024)	(.020)	(.032)	(.021)	(.008)
commodity (D)	**-.162*****	**-.167****	-.025	**-.177****	**-.184****	-.053
	(.009)	(.010)	(.920)	(.016)	(.015)	(.798)
const	.412	.489	.390	-	-	-
	(.000)	(.000)	(.080)			
Buyer-FE (11)	**no**	**yes**	**yes**	**no**	**yes**	**yes**
# observations	127	127	127	127	127	127

The table reports regression results for the following dependent variable: Frequency of quality problems arising (in percent). OLS: Coefficients and (p-values) reported. Fractional probit: Avg. marginal effects and (p-values) reported. Robust standard errors are clustered at the level of buyer-seller pairs. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 1: Trust and investment proxied by quality issues: OLS and fractional probit results

In Table 1 we present the results of three specifications, for OLS in columns 1 to 3 and fractional probit in colums 4 to 6. The first specification (columns 1 and 4) leaves the dummies for the individual buyers out, while the second specification (columns 2 and 5) includes them. For both of these specifications, the results are highly intuitive and as one would expect. Higher levels of trust are associated with significantly fewer quality problems arising. Neither the size of the supplier in question nor the number of competitors supplying the given part matter for quality issues. For larger parts (systems and modules), the type dummies show that quality problems arise as expected with a significantly higher probability. Including buyer dummies increases the strength of the central relationship noticeably. Thus, in the absence of buyer fixed effects, the effect of trust on quality (via the suppliers' investment) is underestimated.

In the third specification (columns 3 and 6), we disentangle how trust and quality issues are associated across different part types. By interacting the trust index with a dummy variable "high-tech", which includes systems and components with significantly higher R&D-cost shares, we see whether changes in the trust level differentially affect high- and low-tech parts. The basic economic factors at play in the relationships between these types of parts should differ substantially. While there is little opportunity for suppliers of commodities and modules to differentiate their products vertically, there is much room for suppliers of high-tech components and systems to do that via relationship-specific investment, which potentially puts them in a different bargaining position vis-à-vis the buyer. This is the theme we explore in the second part of our theoretical model below.

One would have expected the additional relationship-specific investment required by high-tech, as opposed to low-tech, parts to increase the effect of trust on the quality of the investment. We observe the exact opposite. The trust parameter for low-tech parts increases in size by about 25% and remains highly significant. By contrast, for high-tech parts, the size of the effect is approximately halved, and drops to a level that is not even close to significant. A comparison of the OLS to the fractional probit specifications shows that the latter are more precise. Still, we only find a significant effect of trust on investment or quality for low-tech parts.

The range of the estimated effects is between 2.77 and 3.95 percentage points lower incidence of quality issues per standard deviation of the trust index (0.79). Notice that the average incidence of quality issues observed in our sample is 14.1%. A one standard deviation increase in the trust index would therefore be associated with a reduction in incidences of quality issues of between 19.6% and 28,0% relative to the average rate.

3.4 Trust and investment: causality and robustness

We now explore the direction of causality, and the robustness of the empirical findings obtained so far. The causality we will explore is that increases in trust induce a higher level of specific investment by the supplier. Determining causality on the basis of cross-sectional data is an issue. In particular, less investment by the supplier could lead to quality problems, which in turn could place a burden on mutual trust especially of the buyer in the disappointing supplier. This could be further exacerbated by some form of confrontation, e.g. legal conflict. However, by our data, quality issues are in no way related to observed legal conflicts between suppliers and buyers. For 99.5% of the part-specific relationships that we observe, the respondents report relationship histories without any legal conflict whatsoever.[24] The absence of legal action is by itself indicative of the importance of the informal nature of the buyer-supplier relationship.

[24] No legal conflicts were reported in all but one of the answers and the one exception reported that no quality issues have ever occurred.

Returning to reverse causality, according to which higher failure rates would let the trust of buyers in a given supplier deteriorate, we can test this hypothesis using an alternative trust measure which captures only the supplier's trust in a given buyer. We observe this only for the cases in which the supplier initiated pre-development cooperation with a particular buyer for the part in question. Here, the supplier was asked to rate how important his trust in the buyer was when considering to initiate cooperation.

The response, for which we use the shorthand $trust_{PD}$, is measured on the same scale as the questions determining the trust index. This trust measure is particularly sensitive to IPR conflicts between the parties, with a strong negative conditional correlation of -0.64. Replacing the trust index by $trust_{PD}$ in the quality regressions, we find that an increase in supplier trust by one unit is associated with a significant, almost 3 percent lower part failure rate for the slightly smaller sample; see Table 2. This indicates that the results we find remain qualitatively identical. We conclude that higher failure rates cannot be purely responsible for reducing the trust of buyers.

	Frequency of Quality Problems	
Variables	(1)	(2)
trust$_{PD}$	**-.027*****	**-.027****
	(.009)	(.012)
supplier revenues (bln)	-.001	-.001
	(.621)	(.711)
# suppliers overall	.001	.001
	(.477)	(.452)
product type		
system (D)	reference category	
module (D)	-.018	-.017
	(.866)	(.875)
component (D)	**-.183***	**-.192****
	(.063)	(.046)
commodity (D)	**-.186****	**-.195****
	(.045)	(.039)
Buyer-FE (11)	**no**	**yes**
# observations	107	107

The table reports regression results for the following dependent variable: Frequency of quality problems arising (in percent) – average marginal effects and (p-values) reported; standard errors are clustered at the level of buyer-seller pairs; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 2: Directed (supplier) trust in pre-development and investment proxied by quality issues: Fractional probit results

The determinants of the trust measure derived in Subsection 3.2 indicated significant sources of variation explaining the realizations of the trust index. These included IP-conflicts, unwanted sharing of supplier IP by buyers at different stages of the development process, price renegotiation demands by the OEM and, as a positive aspect, the buyer co-absorbing the supplier's development risks. Each of these determinants was significantly related to the trust index. In the second column of Table 10 in the Empirical Appendix, we regress the likelihood of quality issues arising separately on each determinant and our standard set of controls. This can be interpreted as a reduced-form instrumental variable approach.[25] If these determinants drive quality issues via their effect on trust, then their effect on the occurrence of quality issues arising should have the opposite sign to their effect on the trust measure. This indeed is the case, as Column (2) of Table 10 shows. For example, an increase in the reported frequency of IPR conflicts by one standard deviation (0.61) would be associated with a 3.6 percentage point higher incidence of quality issues arising for the part in question. Except for price renegotiations in series production, each of the (negative) buyer behaviors associated with the Lopez procurement strategy has a detrimental and sizable significant effect on whether quality issues arise for the part in question. These patterns of buyer behavior, in particular with regard to IPRs, were certainly not determined by current quality issues. Our central argument against reverse causality is related to these observations. Building mutual trust is a long term endeavor that is influenced by a host of factors other than the failure rate of a particular part for a given car model. The benchmarking study was explicitly motivated by a "crisis of trust" in automotive procurement in Germany, that resulted from confrontational procurement practices introduced in the early 1990s – a good decade earlier.

In the remainder of this subsection, we conduct a number of other robustness checks. First, we run our central regressions with our trust index normalized by the "importance or price" variable, as indicated above. Tables 11 and 12 in the Empirical Appendix contain the results. They are qualitatively identical. Second, in our empirical specification above we might be omitting some characteristic of suppliers which positively affects both trust and quality. While we did introduce buyer-dummies to control for complementary buyer investments and specifics of buyer's overall procurement strategies, we controlled on the supplier side only for for supplier revenue. In other words, aspects, other than those related to size or bargaining power, may not have been fully captured. For example, supplier A may have a superior engineering department, systematically reducing failure rates and thereby improving relationship trust. To take account of this type of issue, we introduce into the investment regression an additional set of fixed effects, supplier dummies column (3), as well as buyer dummies interacted with part dummies column (4), yielding:

$$y_{ijs} = \beta * x_{ijs} + \gamma * Z_{ijs} + \kappa + \alpha_j + \mu_s + \alpha_j * type_i + \epsilon_{ijs}, \tag{2}$$

where y_{ijs} is the probability that quality problems arise for part i supplied to buyer j by supplier s, x_{ijs} the trust measure related to supplying part type i to buyer j by supplier s, Z_{ijs} are the usual control variables (now omitting supplier revenues), κ is a constant, α_j

[25] The relatively small number of observations in the sample involves the standard issues associated with weak instruments in IV-regressions.

Variables	Frequency of Quality Problems (1)	(2)	(3)	(4)	(5)
trust index	**-.035****	**-.043*****	**-.040****	**-.045****	.002
	(.021)	(.007)	(.026)	(0.027)	(0.958)
supplier revenues (bln)	-.001	-.001	omitted	omitted	omitted
	(.419)	(.315)			
# suppliers overall	.001	.001	-.001	-.002	-.002
	(.328)	(.319)	(0.392)	(.179)	(0.263)
product type					
system (D)	reference category				
module (D)	-.028	-.033	-.064	.065	0.004
	(.736)	(.688)	(.353)	(.447)	(0.970)
component (D)	**-.165****	**-.176****	-.073	.083	.020
	(.032)	(.021)	(.247)	(.435)	(0.812)
commodity (D)	**-.177****	**-.184****	-.069	.036	-.022
	(.016)	(.015)	(.233)	(.256)	(0.752)
Buyer-FE (11)	**no**	**yes**	**yes**	**yes**	**yes**
Supplier-FE (13)	**no**	**no**	**yes**	**yes**	**yes**
Buyer-Part-FE	**no**	**no**	**no**	**yes**	**no**
Buyer-Supplier-FE	**no**	**no**	**no**	**no**	**yes**
# observations	127	127	127	127	127

The table reports regression results for the following dependent variable: Frequency of quality problems arising (in percent); average marginal effects and (p-values) reported; robust standard errors are clustered at the level of buyer-seller pairs; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 3: Robustness of trust and investment proxied by quality issues introducing additional sets of dummies: Fractional-probit results

the buyer fixed-effect, μ_s the supplier fixed-effect (dummies identifying the 13 suppliers) and $\alpha_j * type_i$ signifies the interaction between buyer and part-type dummies. With this we allow for part types to differ across buyers. For instance, the interaction term would capture the effect that would arise if buyer A had different quality standards for systems than buyer B. Finally, in column (5) we insert a control for the specific relationship between buyer and supplier, that is an interaction of buyer and supplier dummies. It is exactly this relationship for which we expect trust to matter. The effects of trust should disappear when controlling for relationship-specific fixed effects.

Table 3 contains the fractional Probit regressions, with the baseline regressions included in columns 1 and 2 for ease of comparison. In the new columns 3 and 4, the coefficient of trust remains almost unchanged. The effects of part characteristics in the baseline regressions are mostly absorbed by the supplier dummies, indicating collinearity between our standard controls and the supplier fixed effects. Our results are therefore robust to the inclusion of supplier dummies as well as interactions of these dummies with part type, implying that heterogeneity with regard to quality demands for given part groups across buyers does not drive our findings. Most importantly, the placebo test in column (5) shows that our results are truly driven by differences in trust and quality across buyer-supplier relationships: when we introduce fixed effects at this level, the association of trust and quality completely disappears.[26]

3.5 Trust and competition

In all phases, pre-development, development and series production, we observe the intensity of competition measured by the number of competing suppliers (in developments) or parallel producers (in series production). Recall the drastic differences between the stages. In pre-development, investment by the supplier is not model- nor even relationship-specific, but closer to basic research into the design of a part. There appears little room for buyer hold-up. By contrast, in the development phase, suppliers invest into adjusting their part design to the buyer's car model-specific requirements. Here the supplier's technological advances—eventually embodied in the blueprint—are at risk of expropriation, if production based on that blueprint is awarded (even partially) to another supplier. Even if patented, the supplier's IPRs are much less well protected than one might expect. Our suppliers report that in the past, in 31% of the development relationships, buyers passed on at least part of their IPRs to competitors without their consent.[27]

In each phase, the buyer can work with one or several suppliers. In development, for example, multiple suppliers may work competitively on blueprints for a given part, with the buyer selecting the most suitable blueprint to move forward into series production. In series production, multiple sourcing implies that the total production volume is shared among multiple suppliers. To assess the trust relationship between buyer and supplier and the levels of competition induced by the typical buyer, we run regressions of the following form:

$$n_{ijs} = \beta * x_{ijs} + \gamma * Z_{ijs} + \kappa + \alpha_j + \epsilon_{ijs}. \tag{3}$$

The dependent variable in our regressions is a count-variable. Therefore we report the results of Poisson regressions with the dependent variable n_{ijs}, the number of competitors including supplier s involved in the pre-development and development phases, and the number of parallel suppliers in production, respectively, of part i supplied to buyer j. Again, we control for the type of part in question, the suppliers' yearly revenues, and the number of suppliers offering the type of product in question in the German market, and run specifications with and without buyer fixed-effects.

Table 4 contains the results of our baseline regressions. In the pre-development phase without relationship-specific investment, columns (1) and (2), we observe no association between trust and the number of competitors, neither without buyer dummies, column

[26]This is not purely a result of a highly specified model, there are 69 degrees of freedom remaining in the specification. Remaining variation is present across sourced part types.

[27]This type of behavior is an example of how past interactions with regard to specific parts and the IPRs embodied therein affect trust in the buyer. Not surprisingly, this buyer behavior is significantly negatively correlated with our trust measure (correlation of -.35, p-value 0.0000).

Variables	Number of suppliers at different stages					
	Pre-Dev.♠		Dev.♣		Ser. Prod.♡	
	(1)	(2)	(3)	(4)	(5)	(6)
trust index	-.026	-.002	**.118****	**.162****	**.133*****	**.121****
	(.582)	(.977)	(.030)	(.012)	(.000)	(.023)
supplier revenues	.001	.003	**.016*****	**.019*****	.001	.002
	(.791)	(.403)	(.004)	(.000)	(.899)	(.641)
# suppliers overall	-.003	-.003	**-.017*****	**-.018*****	**-.014*****	**-.013*****
	(.380)	(.392)	(.000)	(.000)	(.000)	(.000)
product type						
system (D)	reference category					
module (D)	-.061	.019	**.681****	**.719*****	0.121	0.161
	(.720)	(.915)	(.012)	(.001)	(.437)	(.277)
component (D)	0̇09	.013	.329	**.339*****	.167	.181
	(.952)	(.935)	(.143)	(.082)	(.287)	(.209)
commodity (D)	.128	.124	**.661*****	**.659*****	**.532*****	**.556*****
	(.378)	(.404)	(.001)	(.000)	(.002)	(.000)
const	.875	.520	-.550	-.928	-.402	-.673
	(.001)	(.113)	(.047)	(.003)	(.063)	(.020)
Buyer-FE (11)	**no**	**yes**	**no**	**yes**	**no**	**yes**
# observations	78	78	127	127	126	126
Pseudo-R^2	.004	.013	.062	.083	.037	.045

The table reports Poisson regression results for the following dependent variables: ♠ Number of suppliers employed during pre-development – coefficients and (p- values) reported – ♣ number of suppliers during the final stage of development – coefficients and (p-values) reported – ♡ number of suppliers at the start of series production – coefficients and (p-values) reported; robust standard errors are clustered at the level of buyer-seller pairs; * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Trust and Competition: Poisson-regression results

(1), nor with, column (2). Despite the smaller number of observations, this is not a result of larger standard errors – especially in the specification with buyer dummies, the coefficient is close to 0.

In development and series production involving intense relationship-specific investment, however, the association between trust and supplier competition is significant and large. In the development phase, an increase of trust by one standard deviation (0.79) is related to about 0.13 or 8.4% more suppliers when compared to the average of 1.55 suppliers involved in this stage. In the series production phase, an increase of the trust index by one standard deviation is associated with 0.11 or 14% more suppliers when compared to the average of 1.27 suppliers engaged in production.

In our model below we interpret this significant and sizeable relationship as an effect of trust on competition. It is perhaps counter-intuitive that higher levels of trust should cause more intense supplier competition in phases which involve idiosyncratic investment. Two results provide further insights into the motivation of the buyer to employ more than one supplier at the later phases: The first is the coefficient of supplier size measured by revenues. Larger suppliers tend to face more competition during the development phase, which may be an effort on the part of buyers to countermand their better bargaining position. In addition, more external market competition among suppliers for a given part, that is a larger set of potential suppliers, is associated with significantly fewer suppliers selected in both the development and production phases. Both of these results are derived while controlling for the type of part in question.

We now again try to empirically better understand the channels through which trust may affect the number of suppliers interacting with the typical buyer w.r.t. a given part, by allowing trust to affect competition differently for high tech and for low tech parts. We again interact the trust index with a high tech-dummy and run regressions for each of the development stages. The results of these specifications can be found in Table 5.

As in the results on trust and investment, the connection between trust and competition is significant only for low-tech parts—and only in development and series production. Joint F-tests reveal that for high-tech parts, there is no significant effect of trust on competition (dev.: p-value 0.36; ser. prod.: p-value 0.95). Notice again that we are controlling for product types through the dummies module, high-tech component and commodity, so this effect cannot be explained through variation across product types. Recall that in both development and series production, a larger set of external competitors in the German market is associated with significantly fewer competitors for a given part as chosen by the buyer.

3.6 Does competition drive all results?

One explanation involving the connection between trust, investment and competition is immediate and should be discussed in detail. Tougher competition amongst suppliers could force them to exert more effort, or could allow the buyer to select higher quality suppliers. Either of these effects could cause lower failure rates. Here, trust would be the *result* of lower failure rates rather than their *cause*.

If this were the explanation for the observed pattern, then we should see significantly lower failure rates in relationships involving tougher competition, and this in all phases, pre-development, development, and series production. We can directly test this alternative hypothesis with the following specification:

$$y_{ijs} = \beta * x_{ijs} + \gamma * Z_{ijs} + \kappa + \alpha_j + \epsilon_{ijs}, \quad (4)$$

where y is the failure rate specific to part i, buyer j and supplier s, x is the number of suppliers at the different stages, Z is the vector of the controls used before, κ is a constant, and α is a buyer-fixed effect.

In this specification, trust would be an omitted variable that simultaneously has a positive effect on competition and on quality, jointly leading to a positive correlation between the two. We run the specifications for the number of suppliers in all three phases

Variables	Number of Suppliers Pre-Dev. (1)	 Dev. (2)	 Ser. Prod. (3)
trust index (high-tech)	-.053	.100	-.004
	(.597)	(.363)	(.946)
trust index (low-tech)	.033	**.185*** **	**.174*** **
	(.674)	(.007)	(.001)
supplier revenues (bln)	.003	**.019*** **	.001
	(.470)	(.000)	(.852)
# suppliers overall	-.003	**-.018*** **	**-.013*** **
	(.442)	(.000)	(0.000)
product type			
system (D)		omitted	
module (D)	-.405	.293	**-.746** **
	(.570)	(.543)	(.042)
component (D)	.021	**.331* **	.141
	(.895)	(.097)	(.277)
commodity (D)	-.300	.232	.141
	(.674)	(.646)	(.130)
const	.768	-.618	-.358
	(.142)	(.179)	(.311)
Buyer-FE (11)	**yes**	**yes**	**yes**
# observations	78	127	126
Pseudo-R^2	.013	.083	.047

The table reports regression results for the following dependent variables: number of parallel suppliers at the different development stages; coefficients and (p-values) reported; robust standard errors are clustered at the level of buyer-seller pairs; * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: Trust and competition for low- vs. high-tech parts: Poisson-regression results

and report the results in Table 6. Furthermore, we present a specification including the trust index in the controls Z, in columns (2), (4) and (6).

In neither phase there is a significant negative effect of the number of competing suppliers on failure rates. Indeed, if the alternative explanation were to hold and the correlation with trust really were only a by-product, then we should see a stronger correlation between competition and failure frequencies than between the two and trust. Yet we observe the opposite. For the number of suppliers in the stages involving relationship specific investment, there is no significant effect, and for pre-development we even get the opposite of the expected sign if the reverse causality were to hold.

When looking at the specifications including the trust measure in the regression, the results remain qualitatively unchanged and the size of the coefficients on competition decreases, which is in line with the previous pattern of findings. Notice that the effect of

	Frequency of Quality Problems					
	Pre-Dev.		Dev.		Ser. Prod.	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
# parallel suppliers	**.039****	**.045*****	-.004	.004	-.010	-.001
	(.031)	(.001)	(.796)	(.788)	(.667)	(.959)
trust index	omitted	**-.053****	omitted	**-.044*****	omitted	**-.041****
		(.018)		(.004)		(.020)
supplier revenues	**.002****	**.002***	-.001	-.001	**-.002***	**-.003***
	(.032)	(.052)	(.350)	(.276)	(.093)	(.065)
# suppliers overall	**.005*****	**.005*****	.001	.001	.001	.001
	(.000)	(.000)	(.394)	(.293)	(.643)	(.619)
product type						
system (D)	reference category					
module (D)	.073	.019	-.020	-.039	**-0.133***	-0.140
	(.452)	(.915)	(.772)	(.625)	(.093)	(.130)
component (D)	**-.206*****	.013	**-.163****	**-.180****	**-.234*****	**-.243*****
	(.001)	(.935)	(.011)	(.015)	(.001)	(.003)
commodity (D)	**-.156*****	.124	**-.176*****	**-.189*****	**-.243*****	**-.247*****
	(.007)	(.404)	(.004)	(.009)	(.002)	(.006)
Buyer-FE (11)	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
# observations	74	74	127	127	126	126

The table reports Fractional Probit-regression results for the following dependent variable: Frequency of quality issues arising for the part in question (in percent) – coefficients and (p-values) reported; standard errors are clustered at the level of buyer-seller pairs; *significant at 10%; ** significant at 5%; *** significant at 1%

Table 6: Investment, competition and trust: Fractional Probit-regression results

trust on quality remains highly significant. We interpret this as a further indication that the driver of the observed pattern actually is trust. The fact that we do not observe significant positive correlation between competition and quality issues indicates that at the margin buyers in fact use additional slack from higher trust to *either* induce additional competition *or* to enforce higher investment by suppliers.

Finally, we briefly discuss alternative reasons for buyers to induce competition among suppliers at the development and series production stages. From the procurement literature we expect to find that more competition has a negative effect on suppliers' returns, for example by limiting their information rents. In the survey, a subset of respondents assess the share of their development costs reimbursed by the buyer via a markup on produced parts. This is a clearly imperfect proxy for the supplier's information rent. Controlling for type classifications and buyer fixed effects, we find that an additional supplier in series production is associated with reductions in the development-cost shares reimbursed via markups by 12.3 percentage points (p-value: .000); compared to an average share of 54.7 percent.[28] Therefore, competition appears unrelated to investment,

[28]Additional suppliers in series production include an additional effect through lower production

but is negatively related to the cost shares assumed by the buyers through markups, which directly implies that suppliers should resent increased competition. These results are in line with our theoretical explanation below and allow us to reject the alternative hypothesis that competition simultaneously drives all of our central results.[29]

We have presented evidence on two important aspects of buyer-supplier relationships in the German automotive industry. First, as one would expect, higher trust in a supply relationship is associated with significantly higher buyer-specific investment by suppliers proxied by lower failure rates (that is higher quality) of parts. Since relationship-specific investment must invariably be higher in high-tech than in low-tech parts, one would expect the association to be stronger in the former rather than the latter. However, our empirical analysis leads to the opposite conclusion, namely a significant association between trust and investment for low-tech, and no association for high-tech parts.

Second, we show that higher trust is associated with significantly more intense supplier competition in those development phases in which a relationship specific investment by the supplier is required – that is, in vehicle specific development and series production – but not in the phase in which supplier investment is not relationship specific, that is pre-development. Again, the association between trust and competition holds exclusively for low-tech parts, while there is no significant effect for high-tech parts.

In the following section, we simultaneously explain these relationships within one model. We demonstrate that in procurement situations involving intense competition amongst suppliers—here, suppliers of low-tech commodities and modules—higher established long term trust allows the buyer to request higher relationship specific investment from a given supplier, and simultaneously enables her to induce more competition in development and series production stages. However, this pattern can no longer be upheld in procurement situations in which the market power between buyers and suppliers is tilted towards the typical supplier—here, the supplier(s) of high-tech components and systems.

4 A model of buyer-supplier relations

In the model below, we focus on key elements of the relational contracts that prevail in the German automotive industry. However, these elements are common to many other long-term incomplete contracting environments where the suppliers' relationship-specific investment is an essential input into the final product.

Based on our empirical observations, we propose a model where the key variables in the contract are determined alternatively by the typical buyer, or by a typical supplier. We identify the equilibrium of the repeated game that is best from the buyer's point

volume per producer.

[29]Tougher competition leading to increased trust would also contradict the evidence available from Japanese lean production. For example, MacDuffie and Helper (1997), when discussing the benefits of introducing Japanese-style relationship-based lean management techniques in procurement, write that "As Sako has pointed out, trust between supplier and customer is essential to achieve these benefits, so switching suppliers could hurt not only the relationship with the supplier that lost business, but also with other suppliers observing this event." (p. 121).

of view (where the buyer has the bargaining power) as well as the equilibrium that is best from the producing supplier's point of view (when the producing supplier has the bargaining power). As we will see, this results in drastic and empirically identifiable differences in the comparative statics with respect to the discount factor, our proxy for the trust measure employed in the empirical analysis. While the case in which the buyer has the bargaining power reflects the relationship among trust, investment, and competition we have empirically seen for the transactions involving low-tech parts, the case in which the supplier has the bargaining power reflects the lack of relationships we have seen for the transactions involving high-tech parts. Studying how the comparative statics of a relational contracting model changes depending on the allocation of bargaining power among the involved parties is novel in the relational contracting literature and can be seen a contribution per se, independent of its ability to explain our empirical results.

4.1 Model elements

In each period t of an infinite sequence of periods a buyer needs to procure an innovative intermediate product. This entails first the development of a buyer-specific blueprint for such a product, which requires an R&D investment $I > 0$ by the typical supplier, and subsequently the production of the intermediate product. Investment is non-contractible. Its cost is sunk and normalized to I for I units of investment.

There are $N > 1$ firms capable of developing and supplying the intermediate product by having invested in (typically) buyer-unspecific predevelopment, not analyzed here. The buyer selects a subset of the N firms. For simplicity we denote this subset by its size $n_t (\leq N)$.[30] In case several suppliers are chosen to develop the product, the suppliers invest independently and competitively. As investment I_t is buyer-specific, it has no value for buyers other than the one for whom the intermediate product is developed.

The value to the buyer of the final product with embedded investment I_t and n_t developing firms is $v(I_t, n_t)$, a function increasing in both arguments, strictly concave and satisfying the Inada conditions. Although a strictly positive partial derivative v_n is not necessary for our results, it fits our empirical environment. When several firms develop a blueprint, the buyer is less exposed to the risk that the development process is overall unsuccessful; furthermore, the activities of any one of the developing firms may generate positive spillovers to other developers and increase the ultimate value to the buyer. In both cases, the marginal value of investment is also increasing in the number of firms, that is $v_{In} \geq 0$. We denote v_0 the value of procurement to the buyer if she stays in the relationship but the supplier's investment is nil, which is clearly independent of n; and v_S the value to the buyer in case she leaves an established procurement relationship and starts procuring anew. The suppliers' outside option is normalized to zero. The investment fully depreciates at the end of the current period.

After the development phase described above, a single supplier is chosen by the buyer to produce the part. (The case of more than one producer, multiple sourcing, is presented in the Theoretical Appendix). Supplier i's cost of production in period t is θ_{it},

[30] In our data we have verified that $N > 1$, so there is effective competition between potential suppliers for each part considered.

assumed to be i.i.d. across suppliers and periods on the support $[\theta_{\min}, \theta_{\max}]$ according to a time-invariant distribution $F(\theta_{it})$. The realization of each supplier's production cost is unknown to the buyer, although, for simplicity and without loss of generality, it becomes known to other suppliers. Within the current period t, the buyer may ask supplier i to produce the intermediate product using the blueprint developed by another supplier j within the same period. Yet, for suppliers that did not participate in the development phase, this necessitates an adjustment cost discussed below.

This procurement process is repeated over an infinite horizon. Independently of the identity of the party with the bargaining power, the typical period t comprises the following stage game (we henceforth delete subscript t to facilitate notation):

t_1 *(Selection for development)*: n potential suppliers are chosen by the buyer to participate in the development of a blueprint for the intermediate product. The buyer and the suppliers agree on a desired minimal level of investment $\underline{I}$.[31] The buyer commits to a transfer w to each one of the n suppliers to be paid at the end of the development phase t_2.

t_2 *(Development)*: Each supplier i that participates in the development stage incurs sunk cost I_i towards his investment I_i. This investment remains unobserved by the buyer until the end of t_4. The buyer pays transfer w to each of the n suppliers.

t_3 *(Selection for production)*: The buyer invites $\tilde{n}$ (with possibly $\tilde{n} > n$) suppliers to compete in an auction for the production contract, allocates the production contract to a unique supplier h, and sets the price p payable on delivery of the intermediate product. When selecting a non-developing supplier to produce with the blueprint developed by a developing supplier, the buyer needs to account for an ex-ante uncertain adjustment cost $k \geq 0$ private to and incurred by her, related to the training of the non-developing supplier selected to produce the part.[32] The number and identity of the $\tilde{n}$ firms invited at the auction is public information. The production cost θ_i for each of these suppliers is then realized.

t_4 *(Production)*: The selected supplier h produces at cost θ_h and receives the transfer p from the buyer. At the end of the stage game, the buyer observes the investment of the n suppliers invited to the development phase of the procurement process.

The assumption that the suppliers are identical ex ante is made to simplify the model. As standard in the relational contracting literature and consistent with evidence from our survey, the transfer w is assumed contractible and, as such, enforceable by the courts.

Both the level I_i invested by the typical supplier i at t_2 and the number $\tilde{n}$ of sup-

[31] To simplify notation, we renumber these n firms so that these are the first n ones. The investment $\underline{I}$ reflects performance specifications in a functional procurement process. These are outcome- rather than effort-oriented.

[32] This naturally reflects the idea that the production of complex parts not developed in-house requires the costly adaptation of skills and tools. Indeed, it corresponds to Lopez's strategy of sending teams of engineers for weeks on site to the non-developing outsiders, to train them to reliably produce the part on the basis of a competing supplier's blueprint. When this threat became credible, his procurement managers started using the winning outsider's bid plus an allowance for the training cost to pressure suppliers to decrease their offers.

pliers admitted to compete for production at t_3 are not contractible and determined in equilibrium. If $\tilde{n} > 1$ the buyer (optimally) attributes the production contract with a second price auction.[33]

Although I and $\tilde{n}$ are not contractible, the infinite repetition of the stage game allows the buyer and the suppliers to rely on relational contracting, threatening to enact mutual punishments after deviations from equilibrium levels of I and $\tilde{n}$. In particular, any supplier l observed at the end of t_4 by the buyer to have deviated and invested at a level $I_l < \underline{I}$ is excluded from all future procurements and replaced with another supplier from the $N - n$ supplixers not invited to the procurement process. The observability of all investments at the end of time t_4 is clearly a strong assumption. However, similar results could be obtained assuming that the buyer only observes (exogenously) imperfect but informative signals of the investments.[34]

Concerning competition for production (stage t_3), if $\tilde{n} > n$, the buyer may end up depriving one of the suppliers of his IPR embodied in his blueprint, by basing the production procurement on this very blueprint without ensuring that its developer is also the winner of the production contract. Hence, we assume that the typical supplier amongst those chosen for development threatens not to invest at all when selected in future procurements if the buyer deviates at t_3 by inviting non-developing outsiders to compete for production based on the blueprint developed by one of the n suppliers selected in the development stage, that is if $\tilde{n} > n$.[35]

As we have seen in the previous sections, there is significant duplication of investment at the development phase. We interpret this observation as an indication that the expected adjustment cost $E(k)$ is large enough so that the buyer prefers to avoid completely unbundling blueprints development and production, that is having just one firm investing for a blueprint and all firms competing for production. At the same time, however, as the Lopez affair showed, when the realization of k is sufficiently low, the

[33]This is the optimal mechanism for the buyer at this stage of the game under the assumption that suppliers cannot collude. See Calzolari and Spagnolo (2009) for an analysis of the interplay between relational procurement strategies and suppliers' collusion. See also Ishihara and Muramoto (2018) for the tradeoff between collusion and relative performance evaluations in relational contracts for teams.

[34]The non-observability of the winning seller's investment before the end of the stage game is consistent with our empirical case. Rather than observing the investment, the buyer can only observe its outcome, which is the failure rate of the part observed when the automobile is bought and used. Non-observability of the investments in blueprints not used in production could be alternatively modeled at the cost of an extra incentive compatibility constraint that prevents a firm i from setting $I_i = 0$, avoiding to win the auction and systematically cashing in w (if positive). This constraint would have no effect on our results.

[35]Our assumptions on the punishment are well reflected in the case study evidence conducted by one of the authors prior to the questionnaire study. It is based on in-depth interviews with key suppliers and buyers regarding their relationships in the recent past that were very much influenced by Lopez's deviation from the constraint not to have non-developing suppliers participate in the procurement process for production. In these interviews, candid examples of confrontational procurement practices were recounted, including cases of proprietary blueprints being made publicly available by the buyer so as to attract the lowest-bidding supplier for production, as well as the supplier reaction to this, namely not to come forward with the required R&D investment. See Müller, Stahl, and Wachtler (2016). Notice that within our model, the buyer's deviation is realistically observed in the entire industry, and therefore, the suppliers collectively punish the buyer.

buyer may be tempted to deviate and invite many competitors for production. We will account and further discuss these possibilities when considering optimal procurement below. We also assume that the buyer cannot make contingent payments such as discretionary bonuses.[36]

The discount factor is one across all phases of the same stage game, and $\delta \leq 1$ across different stage games. In line with the emerging literature on trust and relational contracts discussed in Section 2 above we interpret δ, which is common to both the buyer and the suppliers, as an indicator of the trust the participants in the game associate with future co-operation. The common δ models the idea reflected in the relevant question in the questionnaire survey, that mutual trust is the commonly understood level of trust.

The game as described has a continuum of equilibria. Indeed a Folk Theorem can be proven in this repeated setting. In our analysis below we focus on two notable equilibria that are identified as the equilibrium most profitable for the buyer, and that most profitable for the seller that participates in the development stage and obtains the production contract, respectively. In the spirit of MacLeod and Malcomson (1998), the idea is that the specific equilibrium that prevails should be the one most profitable for the agent that holds the market power regarding the development and production of the part considered.

4.2 Incentive Compatibility in Relational Procurement

We now characterize the main properties of the equilibria in our model. We consider symmetric stationary relational contracts where both the n suppliers each develop the required blueprint by undertaking investment $I \geq \underline{I}$, and the buyer abstains from inviting more than the announced n suppliers to compete for the production contract.[37]

In the development phase, each of these suppliers decides how much to invest, anticipating the expected rent $\beta(n)\pi(n)$ associated with the production contract in this stage game, where $\beta(n)$ denotes the probability that a given supplier will obtain the production contract among the n suppliers, and $\pi(n)$ the expected rent accruing from production to that supplier. Since by assumption the suppliers are *ex ante* identical, $\beta(n) = 1/n$.

If $n > 1$, the expected rent obtained by the winning supplier is $\pi(n) = \theta^e_{(2)}(n) - \theta^e_{(1)}(n)$, where $\theta^e_{(1)}(n)$ is the expected cost of the efficient supplier and $\theta^e_{(2)}(n)$ that of the second-most efficient one. In the second price auction the suppliers reveal their costs in their bids. The winning supplier then sells his intermediate product at the price $p = \theta_{(2)}(n)$. If instead $n = 1$, then obviously $\beta(1) = 1$, the single supplier's expected

[36] When the number of firms selected in the pool is $n < N$, as is the case for all observations in our data, discretionary monetary bonuses are not credible in equilibrium, because the buyer would renege on the promised bonus and replace the current supplier at no cost. Empirically, we are not aware of public or private procurement practices in which ex post monetary bonuses are regularly used, and the German car industry is no exception.

[37] Stationarity is without loss of generality with a single agent-supplier (Levine, 2003). Board (2011) has shown that a principal-buyer may want to follow a non-stationary initial phase that leads to a stable group of preferred agents-suppliers. The equilibria that we consider here can be seen as the long-run steady state of this type of transition.

rent is $\pi(1) = p - \theta^e(1)$ where $\theta^e(1) = E(\theta)$, and p is the price the buyer and the supplier agree to at t_3.

A non-deviating supplier will optimally just satisfy the buyer's requirement by investing $I = \underline{I}$. His expected payoff over the infinite horizon game is then

$$[w - \underline{I} + \beta(n)\pi(n)]\frac{1}{1-\delta}.$$

If instead the supplier decides to deviate and invest less than required, then he knows that the buyer will observe the deviation at the end of the stage game and he will be excluded from all future procurements. Accordingly, it is optimal for him to set $I = 0$, and his expected profit is

$$w + \beta(n)\pi(n).$$

The supplier prefers not to deviate and to invest $\underline{I}$ if the incentive constraint

$$w + \beta(n)\pi(n) \geq \frac{\underline{I}}{\delta} \tag{5}$$

is satisfied. Hence he chooses $\underline{I}$ as required if the sum of the transfer w and the expected rent from winning production $\beta(n)\pi(n)$ is not smaller than the contemporaneous cost of the required investment $\underline{I}/\delta$. This cost is high if δ is small. All else given, in such a case the typical supplier faces a stronger temptation to cheat in the investment phase, and to cash in the informational rent in the production phase.

Let

$$p^e(n) = \begin{cases} \theta^e(1) & \text{if } n = 1 \\ \theta^e_{(2)}(n) & \text{if } n > 1 \end{cases}$$

be the price the buyer expects to pay when n firms compete for production.

When the n suppliers choose the required investment $\underline{I}$ in the development stage, the buyer's infinite horizon payoff at t_3 is

$$v(\underline{I}, n) - p^e(n) + [v(\underline{I}, n) - nw - p^e(n)]\,\frac{\delta}{1-\delta}.$$

Alternatively, at t_3 the buyer could deviate and invite $\tilde{n} > n$ suppliers to compete. In this case it would be optimal for the buyer to choose $\tilde{n} = N$, that is, to invite all available suppliers within the current stage game in order to take advantage of selecting the supplier with the lowest production cost from the largest set possible, thus paying a price $p^e(N)$ smaller than $p^e(n)$. Consequently, following a deviation, the buyer would expect that no supplier would ever invest in the future, and thus set the transfers w' so as to extract all the sellers' informational rents. The buyer's expected discounted payoff from deviating would be

$$\{v(\underline{I}, n) - p^e(N) - k[1 - n\beta(N)]\} + [v_0 - Nw' - p^e(N)]\,\frac{\delta}{1-\delta}, \tag{6}$$

where the terms in the first bracket reflect her return in the current period, accounting for the cost of adapting the technology in case the producer ends up being a non-developer; and those in the second bracket her returns in the future stage games (where the buyer would have to rely on zero investment, maximal competition and transfer w').[38]

The buyer prefers not to deviate by inviting to the procurement contest for production more than the n participants in the development stage, if the incentive constraint

$$\delta\left[v(\underline{I}, n) - nw - (v_0 - Nw')\right] + (1-\delta)k\frac{N-n}{N} \geq p^e(n) - p^e(N) \tag{7}$$

is satisfied. The right hand side is the expected savings in the buyer's payment for the production of the intermediate good from having all N rather than n firms compete. The left hand side is instead the loss in the value of procurement she will face in the future, net of the difference between the equilibrium transfers nw and the ones associated to a deviation Nw' and the cost of adaptation. Clearly, the buyer's incentive to deviate is strongest when the cost of adaptation k is minimal, so that if we solve for the case $k = 0$ we obtain the incentive compatible relational contract for the buyer for any positive value of k.

All else given, when δ is small the buyer also has a stronger temptation to deviate, benefiting from the (expected) reduction in the cost of production.

4.3 Buyer's Market Power

Here we identify and analyze the equilibrium procurement program that is most profitable for the buyer. The optimal procurement program $\mathcal{P}_B$ of the buyer is

$$\begin{array}{lll} \max\limits_{\underline{I}, w, n} & \left[v(\underline{I}, n) - wn - p^e(n)\right]\dfrac{1}{1-\delta} & \\ s.t. & w + \beta(n)\pi(n) \geq \underline{I}/\delta & (IC_s) \\ & \delta\left[v(\underline{I}, n) - nw - (v_0 - \pi(N))\right] + (1-\delta)k\frac{N-n}{N} \geq p^e(n) - p^e(N). & (IC_b) \end{array} \tag{8}$$

If the buyer wants to induce high investment, she has to account for the typical supplier's incentive not to deviate, represented by (IC_s). Increasing the number n of competing suppliers has several effects. First, it reduces the expected price $p^e(n)$ the buyer has to pay, as production costs are drawn from a larger set of suppliers. Second, it reduces the buyer's temptation to deviate, since the difference in the production cost she has to bear between inviting n firms vs. all N firms to compete, $p^e(n) - p^e(N)$ in (IC_b), decreases in n.[39] Finally, it adversely affects the typical supplier's incentive to provide the required investment, because the expected rent $\beta(n)\pi(n)$ to the supplier also decreases in n.

It is immediate to see that in the optimum the buyer always reduces the (positive or

[38] The expected cost of adaptation (third expression in the first bracket in equation (6)) reflects the idea that all N firms are treated equally at the auctions. Although the expression of this cost would be different if the buyer treated differently those in n and the others, the idea and the consequences of the adaptation costs would remain the same.

[39] In (IC_b) we also account for the fact that when $n = N$ the buyer optimally sets $w' = \beta(n)\pi(n)$).

negative) transfer w to a minimum, so that the incentive constraint (IC_s) is binding:

$$w + \beta(n)\pi(n) = \underline{I}/\delta, \tag{9}$$

which both increases the value of her objective function and relaxes her incentive constraint (IC_b). This leads to a simple yet interesting set of observations on the two main procurement choice variables: the level of competition n and of investment $\underline{I}$.

Proposition 1 *In the equilibrium optimal for the buyer, a higher discount factor δ is associated with*

(i) a higher level of investment $\underline{I}$, for given n,

(ii) a larger number of suppliers n, for given $\underline{I}$.

Hence, when δ increases, the buyer can afford to invite a higher number n of competing suppliers (at given w and $\underline{I}$), which implies a lower expected production cost. An analogous reasoning applies to result (i). The simple, yet general idea is that a higher discount factor δ grants the buyer some "slackness" in dealing with suppliers' incentives, which in turn translates into better procurement terms: more competition—that is lower cost of production—and/or higher investment—that is higher value for the final product.[40]

The *overall* effects of a change of δ on the actual terms of procurement that solve $\mathcal{P}_B$ are more involved than the comparative statics of Proposition 1. Imagine, for example, that an increase of δ induces a higher level of investment. The overall effect of this increase in δ on n must then account not only for the *direct effect* described in point (ii) of Proposition 1, but also for the *indirect effect* due to the increased investment. If the latter is large enough, then a higher δ may actually call for a reduction in the number of firms, because the buyer should grant larger informational rents to create incentives for the selected suppliers to invest even more. Towards accounting for the indirect effects, we need to solve the buyer's procurement program $\mathcal{P}_B$ and verify the effect of δ on optimal procurement $(\underline{I}^*_B, n^*_B)$.

Rather than providing a full solution to program $\mathcal{P}_B$, here we exploit some of its properties to verify conditions under which the general idea stated above—the "slackness" associated with an increase in the discount factor—induces the buyer to procure with both higher investment *and* more suppliers.

Since w is implicitly defined by (9), we can rewrite the buyer's per-period objective

[40] In this case the typical supplier's incentive constraint IC_S induces the relevant relationships. One could argue that the discount factor relevant here refers to *the buyer's expectation about the typical supplier's* trust in the continuation of the relationship, rather than (the supplier's assessment of) the buyer's perception of *mutual* trust as asked in the survey. That question was formulated as the best proxy to maintain anonymity. This is also the reason for formulating the model with a joint discount factor.

function as a function of the two main decision variables $\underline{I}$ and n,

$$H(\underline{I}, n) \equiv v(\underline{I}, n) - n\frac{I}{\delta} - \theta^e_{(1)}(n), \tag{10}$$

where the *actual cost of development* $(n\underline{I})/\delta$ encompasses the cost of providing the n suppliers with the incentives to invest (and clearly $\theta^e_{(1)}(1) = \theta^e(1)$). For a given n, the maximizer of $H(\underline{I}, n)$ is defined by

$$v'(\underline{I}, n) = \frac{n}{\delta}. \tag{11}$$

This condition shows that if δ increases and the optimal number of firms n^*_B remains unaffected, then the optimal level of investment increases.

Proposition 2 *In the equilibrium optimal for the buyer, an increase of the discount factor δ necessarily induces an increase of* at least *one of the two optimal procurement variables n^*_B and $\underline{I}^*_B$. Both n^*_B and $\underline{I}^*_B$ increase in δ if $v(\cdot, n)$ is sufficiently concave (with respect to I), that is if the indirect effect is not too strong.*

In the Theoretical Appendix we illustrate the sufficient condition on the value of investment $v(\cdot, n)$. Proposition 2 confirms that the general idea of the "slackness" induced by a higher discount factor δ also pertains to the two *optimal* control variables for the buyer, n^*_B and $\underline{I}^*_B$.[41]

This comparative statics result explains the first half of our empirical findings: for low-tech parts, where there are many potential developers and the buyer has the bargaining power, investment and competition both increase with trust.

In identifying the equilibrium procurement program that is most profitable for the buyer we have focused on a relational contract where each of the n suppliers develops the required blueprint and the buyer invites these suppliers only to compete for the production contract, i.e. $\tilde{n} = n$. As discussed above, however, the buyer and her suppliers might agree on a different relational contract that unbundles the development and production phases, saving the costs of multiple blueprints but incurring the cost of adapting the blueprint developed by some supplier to the production line of someone else. In the Theoretical Appendix we further discuss the possibility of unbundling development and production. We show that whenever the expected cost of adaptation $E(k)$ is large enough, unbundling development and production is dominated by the relational contract considered here. We also show that our results qualitatively hold as long as the buyer does not systematically open competition for production to all potential suppliers (i.e. allowing for $n \leq \tilde{n} < N$) .[42]

[41]The optimal transfer w^*_B is actually a residual variable determined by the binding constraint (9), which shows that increases of both n^*_B and $\underline{I}^*_B$ tend to actually increase the transfer that the buyer has to pay, if not sufficiently counterbalanced by the higher δ. Thus one cannot expect a clear relationship between δ and w^*_B.

[42]The case study evidence collected in 2005/06 for our industry shows that the blueprint submitted by the typical supplier is very much conditioned by the technology available to him, technologies vary

In the Theoretical Appendix we also show that the results of Proposition 2 carry over the case of multiple sourcing (Proposition 4). In addition we show that, consistently with our findings (see Section 3.5), a larger δ induces the buyer to move from single-sourcing to multiple sourcing.

4.4 Supplier's Market Power

We now focus on the equilibrium that is most profitable for the supplier that is involved in both the development and production stages. In other words, we identify the equilibrium where $n = 1$ while, however, the buyer can still deviate at the stage of allocating the production contract and open the competition for the production contract to the N suppliers. At the end of this subsection, we see that our argument straightforwardly generalizes to the case where $n > 1$.

The optimal procurement contract is now such that $n_S^* = 1$ and the procurement program $\mathcal{P}_S$ is

$$\begin{array}{lll} \max\limits_{\underline{I},w} & [w + p^e(1) - \theta^e(1) - \underline{I}]\dfrac{1}{1-\delta} & \\ s.t. & \delta\,[v(\underline{I},1) - w - (v_0 - Nw')] + (1-\delta)k\frac{N-1}{N} \geq p^e(1) - p^e(N) & (IC_b) \\ & w + p^e(1) - \theta^e(1) \geq \underline{I}/\delta. & (IC_s) \end{array} \tag{12}$$

As discussed above, we account in the (IC_b) constraint for the possibility that if the buyer deviates, she can still rely on a competitive auction (with zero investment by the supplier and $w' = \beta(N)\pi(N)$). The logic is that the supplier's market and bargaining power comes from his prominent role and ability to invest, so that when there is no investment in equilibrium his prominence disappears.

As when the buyer has bargaining power, here the supplier optimally increases w up to the point where the other side's incentive compatibility constraint (IC_b) binds. Substituting, the program $\mathcal{P}_S$ becomes

$$\begin{array}{lll} \max\limits_{\underline{I}} & [v(\underline{I},1) - \underline{I} - K]\dfrac{1}{1-\delta} & \\ s.t. & v(\underline{I},1) - K \geq \underline{I}/\delta. & (IC_s) \end{array} \tag{13}$$

where

$$K \equiv v_0 - Nw' + \frac{1}{\delta}\left[p^e(1) - p^e(N) - (1-\delta)k\frac{N-1}{N}\right] \tag{14}$$

depends on N and δ but not on $\underline{I}$.

---

across suppliers, and the winning supplier typically employs his technology. In this environment the costs of adaptation can be very large, explaining why the relational contract that we expect to prevail is the one studied in this section. Nevertheless, the production-adaptation expected cost $E(k)$ may significantly differ between products, with more complex ones, like our "systems", displaying higher cost than standardized ones, like our "commodities". This seems to be indeed the case in our data as we observe that the number of producers is larger than that of developers in 6.9% of the observations regarding commodities, 3.7% for modules, and it is never the case for complex systems.

We can therefore distinguish two alternative characterizations of the equilibrium relational contract that is most profitable for the supplier.

Denote $\underline{I}^*$ the first-best investment defined by

$$v'(\underline{I}^*, 1) = 1. \tag{15}$$

If the (IC_s) constraint is satisfied when the investment level is $\underline{I}^*$, then the relational contract is such that $\underline{I}_S^* = \underline{I}^*$. If instead the (IC_s) constraint is violated at the investment level $\underline{I}^*$, then the optimal investment I_S^* is such that (IC_s) binds:

$$v(I_S^*, 1) - K = I_S^*/\delta \tag{16}$$

and, clearly, underinvestment occurs in equilibrium: $I_S^* < I^*$.

The proposition below follows immediately from equation (16) above.

Proposition 3 *In the equilibrium optimal for the supplier, $n_S^* = 1$, the optimal investment is:*

- $I_S^* = \underline{I}^*$ *and an increase of the discount factor δ is not associated with any change in the optimal level of investment I_S^*;*
- $I_S^* < \underline{I}^*$ *and an increase of the discount factor δ necessarily induces an increase in the equilibrium level of investment I_S^*.*

This proposition provides us with an explanation of the other side of our empirical findings. For high-tech parts, where there are few potential developers with considerable bargaining power, investment and competition need not increase with trust.

Although we have considered here the case with a single seller, $n = 1$, and the supplier's optimal relational contract, the logic is the same with $n > 1$ suppliers with bargaining power. They would set w so that the buyer's incentive constraint (IC_b) binds. As in Proposition 3, we can show (see the Theoretical Appendix) that when the (IC_s) constraint is not binding the pool of suppliers does not change size with a change in δ (as with high-tech parts) and the investment $\underline{I}_S^*$ does not change either. This is different from the case with buyer's bargaining power, Proposition 2, according to which if n does not change, then an increase of δ must induce an increase in $\underline{I}_B^*$. Moreover, we can also show (see the Theoretical Appendix) that n and I should be negatively associated when suppliers have the bargaining power.

We conclude this section with the following observations that again relate the results of our equilibrium characterization (Proposition 2 and 3 above) to our empirical findings in the previous sections. The careful description of the procurement process of parts by German car manufacturers with our model allows to infer that whenever we observe that the level of trust between suppliers and OEM is positively correlated with *both* the quality of the investment in the development stage *and* the number of suppliers that are involved in such development stage, we should conclude that the market power is in the hands of the buyer. The buyer chooses the suppliers' incentive constraint (IC_S)

to be binding, so that an increase in the discount factor δ positively affects both the equilibrium investment level I_B^* and the number of suppliers n_B^*.

If we instead observe that the level of trust between suppliers and OEM is related to *neither* the quality of the investment in the development stage *nor* the number of suppliers involved in it, then the (IC_S) constraint does not bind. Since in every equilibrium of the repeated game where the buyer has some bargaining power the (IC_S) constraint binds we can conclude that we necessarily are in a setting where the bargaining power, because of the market structure, rests on the supply side. We then are in a situation where the level of investment is such that $I_S^* = I^*$.

Summarizing, by relating our equilibrium characterization to our empirical findings, we identified a compelling explanation for a puzzling and rich empirical evidence. Not only relational contracts are key in this important industry, we also show them adapting to the parties' market power.

5 Concluding remarks

Empirical research on relational contracts and their effects is sparse. One reason is that the successful implementation of such contracts requires adequate summaries of multi-dimensional expectations that are not easily grasped in empirical research. The notion of trust provides such a summary. Almost all empirical research on trust has focused on the willingness of individuals to trust others in general. In contrast, we here shed light on the role of trust in specific pairwise economic relationships generated by the exchange of specific commodities. We do this by means of an empirical analysis of first-tier buyer-supplier relationships in the German automotive industry. It is complemented by a theoretical analysis in which we simultaneously rationalize our empirical findings.

We first demonstrate empirically a theoretically well known relationship that higher levels of trust are associated with higher relationship-specific investment. Yet surprisingly, we find that association to be strong in the development and production phases for low-tech parts only, and to disappear in the interaction related to high-tech parts—where we *expected* it to be strong. Even more surprisingly, we find that higher levels of trust are associated with more intense competition amongst suppliers as induced by the buyer. Again, this association is significant in the development and production of low-tech, and insignificant in that of high-tech parts. We apply several tests for robustness and reverse causality to our preferred explanation that the effects are caused by changes in the buyer-supplier trust relationship.

We then develop a relational contracting model involving one buyer and several suppliers involving components of buyer and supplier behavior that are unobservable at the relevant decision stage, and thus enforceable only via a higher continuation value. In that infinitely repeated game, opportunistic short term rent-seeking is dominated by the value associated with long-term cooperation.

We show that, as long as the buyer—as in low-tech markets—has the controlling market power in the relationship and thus can press the suppliers to their incentive constraint, an increase in mutual long term trust allows the buyer to induce a higher relationship-specific investment by the typical supplier, and to increase competition among the suppliers in both development and series production, also accounting for multiple sourcing. However, that possibility evaporates once the market power between the buyer and the supplier(s) is tilted towards the leading supplier—as is the case in high-tech markets.

Buyer-supplier relationships of the type discussed here are neither restricted to the sector nor the country discussed here. They are characteristic of pre-product markets for many other complex products, such as (high-speed) trains, aircraft, defense, or aerospace gadgets.

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Empirical Appendix

Variable	Mean (Std. Dev.)	Min	Max	Obs.
Overall				
Trust index	4.83 (.79)	1.5	6	296
Trust index (n)	- .63 (1.06)	-4	2.7	295
Systems				
Trust index	4.82 (.79)	3.2	6	43
Trust index (n)	- .70 (0.95)	-2.5	1	43
Modules				
Trust index	4.83 (.71)	3.1	6	62
Trust index (n)	- .61 (1.09)	-2.6	2	62
Components				
Trust index	4.89 (.72)	3	6	72
Trust index (n)	- .63 (1.04)	-3	2.7	71
Systems				
Trust index	4.80 (.87)	1.5	6	119
Trust index (n)	- .63 (1.10)	-4	2.3	119

The Table contains descriptive statistic of the trust indices employed in our analysis overall and differentiated by type of product. Trust index is the arithmetic mean of the available responses to the question: *Please evaluate the importance of mutual trust between the supplier and OEM for the OEM's supplier selection*, rated on a six point scale from 1 (no relevance) to 6 (very important) across the three phases pre-development, development and series production.Trust index (n) is the normalized trust index, composed of the mean of the differences between the importance of mutual trust and the importance of price.

Table 7: Trust index summary statistics

Variable	Mean (SD)	Min	Max	Obs.
Frequency of quality issues arising (part specific)	.16 (.21)	0	1	197
Number of competing suppliers during pre-development	2.18 (.83)	1	5	124
Number of competing suppliers during development	1.52 (.91)	1	5	194
Number of suppliers selected at start of production	1.20 (.60)	1	5	216
Markup compensation for development (share of costs)	.55 (.31)	.1	.9	196
Frequency of IPR conflicts PD (fraction)	.10 (.15)	0	.75	123
Frequency of IPR leaks by buyer (PD) (fraction)	.32 (.24)	0	1	245
OEM risk sharing dev. costs (5-point scale)	1.89 (.77)	1	4	222
Frequency of IPR conflicts DEV (fraction)	.31 (.21)	0	1	182
Frequency of IPR leaks by buyer (DEV) (fraction)	.26 (.21)	0	.83	162
Frequency of lump-sum price renegotiation (fraction)	.20 (.23)	0	.83	193

The Table contains descriptive statistic of the dependent and independent variables employed in our analysis.

Table 8: Dependent and independent variables summary statistics

	trust ind.	trust ind. (n)	fail. pr.	mu. comp.	# sup. PD	# sup. dev	# sup. SP
trust index (n)	**0.820*** **						
(p-level, obs)	(.000, 295)						
failure prob.	**-.195** **	**-.156***					
(p-level, obs)	(.015, 155)	(.052,155)					
mu. comp. share	**.181*** **	**.137** **	**.283*** **				
(p-level, obs)	(.011, 196)	(.056, 196)	(.003, 110)				
# suppliers PD	-.109	**-.156***	-.111	.0017			
(p-level, obs)	(.227, 124)	(.084, 124)	(.334, 78)	(.877, 86)			
# suppliers dev	**.119***	.039	-.066	-.079	**.434*** **		
(p-level, obs)	(.010, 193)	(.595, 193)	(.461, 127)	(.389, 122)	(.000, 111)		
# suppliers SP	.042	.075	-.123	**-.252*** **	**.412*** **	**.519*** **	
(p-level, obs)	(.540, 216)	(.273, 216)	(.169, 126)	(.000, 192)	(.000, 86)	(.000, 136)	
supplier rev.[a]	.083	.013	-.077	.074	.122	**.160** **	.013
(p-level, obs)	(.153, 296)	(.828, 295)	(.284, 197)	(.301, 196)	(.178, 124)	(.026, 194)	(.850, 216)

The Table displays pairwise correlations between the main variables of interest. Trust is negatively correlated with the number of competitors during pre-development (where investments by the supplier are not relationship-specific). The sign changes during the subsequent development and production stages. Competition in the later stages is associated with significantly lower shares of compensation for development expenditures.

Table 9: Pairwise correlations of the main variables of interest ([a] Supplier 2007 revenues in Euro bln.)

	Trust Index	**Frequency Quality Problems**
Pre Development	(1)	(2)
Frequency IPR conflicts	**-.471*****	**.058****
	(0.000)	(0.011)
How often does OEM leak supplier's IPR	**-.270*****	**.024***
	(.000)	(0.059)
OEM shares risk of higher development costs	**.134****	.016
	(.041)	(0.424)
Development		
Frequency IPR conflicts	**-.230*****	**.038****
	(.001)	(0.016)
How often does OEM leak supplier's IPR	**-.131****	**.019****
	(.017)	(0.045)
Series Production		
Frequency lump sum price renegotiation	**-.165*****	-0166
	(0.002)	(0.200)

The table is based on the results of separate (1) OLS and (2) fractional probit regressions, in which (1) trust index and (2) probability of quality issues occurring is the dependent variable. As independent variables, the individual trust determinant and controls for part characteristics were included. We report the (1) coefficient and (p-value), (2) average marginal effect and (p-value) of the respective trust determinant.* significant at 10%; ** significant at 5%; *** significant at 1%

Table 10: Determinants of trust index and their effect on part quality

Variables	**Frequency of Quality Problems** (1)	(2)	(3)	(4)	(5)
trust index (n)	-.014	**-.024****	**-.267****	**-.037****	-.010
	(.250)	(.038)	(.041)	(0.014)	(0.715)
supplier revenues (bln)	-.001	-.002	omitted	omitted	omitted
	(.352)	(.253)			
# suppliers overall	.001	.001	-.002	-.002	-.002
	(.390)	(.418)	(0.321)	(.135)	(0.235)
product type					
system (D)			reference category		
module (D)	-.032	-.042	-.087	.018	-0.007
	(.683)	(.593)	(.205)	(.823)	(0.944)
component (D)	**-.165****	**-.175****	-.076	.053	.027
	(.020)	(.013)	(.212)	(.626)	(0.757)
commodity (D)	**-.181*****	**-.189*****	-.084	-.005	-.020
	(.007)	(.006)	(.123)	(.819)	(0.780)
Buyer-FE (11)	**no**	**yes**	**yes**	**yes**	**yes**
Supplier-FE (13)	**no**	**no**	**yes**	**yes**	**yes**
Buyer-Part-FE	**no**	**no**	**no**	**yes**	**no**
Buyer-Supplier-FE	**no**	**no**	**no**	**no**	**yes**
# observations	127	127	127	127	127

The table reports fractional probit regression results for the following dependent variable: Frequency of quality problems arising (in percent). Avg. marginal effects and (p-values) reported. Trust index (n) is the alternative normalized trust index using the differences in importance between trust and price. Robust standard errors are clustered at the level of buyer-seller pairs. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 11: Robustness: Alternative trust measure and investment proxied by quality issues (Fractional probit results)

Variables	Number of suppliers at different stages					
	Pre-Dev.♠		**Dev.♣**		**Ser. Prod.♡**	
	(1)	(2)	(3)	(4)	(5)	(6)
trust index (n)	-.042	-.032	**.059***	**.103***	**.115*****	**.128*****
	(.195)	(.429)	(.066)	(.052)	(.007)	(.007)
supplier revenues	.002	.004	**.024*****	**.027*****	.005	.006
	(.588)	(.240)	(.000)	(.000)	(.260)	(.122)
product type						
system (D)	reference category					
module (D)	-.080	-.003	**.707****	**.775*****	0.139	0.207
	(.629)	(.429)	(.023)	(.003)	(.424)	(.193)
component (D)	0̇04	.018	.292	.313	.135	.151
	(.979)	(.913)	(.265)	(.225)	(.428)	(.307)
commodity (D)	.106	.116	**.564****	**.584****	**.443****	**.484*****
	(.448)	(.433)	(.018)	(.011)	(.015)	(.001)
const	.689	.426	-.271	-.509	-.053	-.275
	(.000)	(.031)	(.337)	(.088)	(.785)	(.116)
Buyer-FE (11)	**no**	**yes**	**no**	**yes**	**no**	**yes**
# observations	78	78	127	127	126	126
Pseudo-R^2	.005	.013	.036	.055	.025	.035

The table reports Poisson regression results for the following dependent variables: ♠ Number of suppliers employed during pre-development – coefficients and (p- values) reported – ♣ number of suppliers during the final stage of development – coefficients and (p-values) reported – ♡ number of suppliers at the start of series production – coefficients and (p-values) reported; robust standard errors are clustered at the level of buyer-seller pairs. Trust index (n) is the alternative normalized trust index using the differences in importance between trust and price. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 12: Robustness: Alternative trust measure and competition: Poisson-regression results

Part description	Number of suppliers Pre-Dev.	Dev.	Ser. Prod.	German market overall
Systems (high tech)				
Brake system	1.8	1.4	1.0	11
Drive assist system	3	1.5	1.0	9
Engine cooling system	2.7	1.1	1.2	9
HVAC system	1.5	1.0	-	8
Injection system	2.0	1.25	1.0	7
Steering system	-	-	1.4	11
Transmission system	3.5	1.0	1.0	5
Modules (low tech)				
Axle module	1.0	1.3	1.5	9
Body module	-	5.0	1.0	9
Brake module	2.0	1.0	-	8
Chassis module	2.0	1.3	1.2	6
Cockpit	-	1.0	-	5
Dashboard	-	-	1.0	9
Filter module	-	1.3	-	15
Gearshift module	2.0	1.8	1.0	26
HVAC module	2.0	1.4	1.0	10
Piston module	-	1.5	1.1	3
Roof module	2.0	1.0	1.0	34
Wiper module	2.0	1.0	1.0	20
Components (high tech)				
Brake component	2.3	1.0	1.0	10
Clutch component	2.1	1.2	1.0	11
Drive assist component	2.3	1.1	1.0	19
Gearshift component	2.0	1.0	1.0	32
HVAC component	-	1.3	1.2	13
Injection component	2.5	1.5	1.0	8
Injection component	2.5	1.5	1.0	8
Piston component	2.5	2.4	1.3	5
Transmission component	2.3	1.2	1.1	25
Commodities (low tech)				
Axle commodity	-	1.0	1.3	16
Bearings	1.6	1.9	1.3	27
Body commodity	2.2	1.0	1.0	25
Brake commodity	3.0	1.7	2.2	22
Clutch commodity	2.0	1.5	1.0	12
Engine cooling commodity	-	1.0	1.0	18
Gasket commodity	1.5	1.7	1.3	14
Starter	3.0	3.0	1.0	8
Steering commodity	2.5	1.3	1.0	8
Transmission commodity	2.0	1.1	1.0	50
V-belt	1.5	2.0	1.2	17

The Table contains the part descriptions of the parts assessed in the benchmarking study sorted by the corresponding type. For each part, the (average, if applicable) number of suppliers in pre-development, development and series production is provided. The last column contains the overall number of suppliers providing this kind of part in the German market at the time of the survey according to the industry procurement database “Who supplies whom”.

Table 13: Descriptives: Types, part descriptions and measures of internal and external competition.

Theoretical Appendix

Proof of Proposition 1

Consider the case $n \geq 2$ and take the binding constraint (IC_s) :

$$w + \frac{\theta^e_{(2)}(n) - \theta^e_{(1)}(n)}{n} = \frac{I}{\delta}$$

We have

$$\frac{\theta^e_{(2)}(n) - \theta^e_{(1)}(n)}{n} = \int_{\underline{\theta}}^{\overline{\theta}} F(\theta)[1 - F(\theta)]^{n-1} d\theta$$

with a slight abuse of notation, we obtain

$$\frac{\partial \left(\frac{\theta^e_{(2)}(n) - \theta^e_{(1)}(n)}{n} \right)}{\partial n} = \int_{\underline{\theta}}^{\overline{\theta}} F(\theta)[1 - F(\theta)]^{n-1} \ln(1 - F(\theta)) d\theta < 0$$

The result in this case follows from the observation that

$$\frac{\partial I}{\partial \delta} = \frac{I}{\delta} > 0$$

together with

$$\frac{\partial w}{\partial \delta} = -\frac{I}{\delta^2} < 0$$

and

$$\frac{\partial n}{\partial \delta} = -\frac{I}{\delta^2} \left[\frac{\partial \left(\frac{\theta^e_{(2)}(n) - \theta^e_{(1)}(n)}{n} \right)}{\partial n} \right]^{-1} > 0.$$

Consider now the case $n = 1$ the binding (IC_s) is then:

$$w = \frac{I}{\delta} - \pi(1) \tag{17}$$

since $\pi(1) = p(1) - E(\theta)$. Clearly in this case we still have

$$\frac{\partial I}{\partial \delta} = w > 0$$

and

$$\frac{\partial w}{\partial \delta} = -\frac{I}{\delta^2} < 0$$

To identify the effect of an increase of δ on n in the case $n = 1$ we need to compare the buyer objective function in the case $n = 1$ and $n = 2$. For a given level of investment I (as contemplated in the proposition), once we substitute the binding (IC_s) in the buyer's objective function we have that $n = 2$ is preferred by the buyer to $n = 1$ if and only if:

$$\left[v(I,2) - \frac{2\underline{I}}{\delta} - \theta^e_{(1)}(2)\right] \frac{1}{1-\delta} \geq \left[v(I,1) - \frac{\underline{I}}{\delta} - E(\theta)\right] \frac{1}{1-\delta}$$

which can be written as:

$$v(I,2) - v(I,1) + \left[E(\theta) - \theta^e_{(1)}(2)\right] \geq \frac{\underline{I}}{\delta}$$

Clearly, for given I, this condition is more likely to be satisfied the higher δ is.

Q.E.D.

Proof of Proposition 2

Notice first that equation (11) implies that if δ increases, either n^* or $\underline{I}^*$ have to increase.

Consider next the overall effect of δ on both endogenous variables n^* and $\underline{I}^*$. We proceed in steps and start from the effect of δ on the optimal number of suppliers n^*. Notice that given some n and being $\underline{I}_n$ the optimal level of investment that maximizes the buyer's per-period objective function $H(\underline{I}, n)$, it could be

$$H(\underline{I}_n, n)\delta \geq v_0\,\delta + (1-\delta)p^e(n) - p^e(N),$$

that is constraint (IC_b) can never be satisfied even considering different values of I. Clearly, in the steps of the proof we disregard these values of n and restrict attention to (and explicitly consider only) those values of n that can allow to satisfy constraint (IC_b).

We first show that when comparing the buyer's payoff associated with any two different numbers of suppliers $n > \tilde{n}$, there exists conditions on $v(\cdot,\cdot)$ such that an increase of the discount factor δ makes the buyer prefer procurement with a larger number n rather than a smaller number $\tilde{n}$ of suppliers. Recall that we are considering $n > \tilde{n}$ which implies $\underline{I}_{\tilde{n}} \geq \underline{I}_n$ where $\underline{I}_n$ and $\underline{I}_{\tilde{n}}$ are the associated optimal level of investments defined by (11). The solution to program $\mathcal{P}$ with n is preferred to $\tilde{n}$ if:

$$\left[v(\underline{I}_n, n) - \frac{n\underline{I}_n}{\delta} - \theta^e_{(1)}(n)\right] \frac{1}{1-\delta} \geq \left[v(\underline{I}_{\tilde{n}}, \tilde{n}) - \frac{\tilde{n}\underline{I}_{\tilde{n}}}{\delta} - \theta^e_{(1)}(\tilde{n})\right] \frac{1}{1-\delta}$$

or equivalently

$$\theta^e_{(1)}(\tilde{n}) - \theta^e_{(1)}(n) \geq \left[v(\underline{I}_{\tilde{n}}, \tilde{n}) - \frac{\tilde{n}\underline{I}_{\tilde{n}}}{\delta}\right] - \left[v(\underline{I}_n, n) - \frac{n\underline{I}_n}{\delta}\right].$$

Now we need to show how the r.h.s. varies with δ. Using the envelope theorem,

$$\frac{d}{d\delta}\left\{\left[v(\underline{I}_{\tilde{n}}, \tilde{n}) - \frac{\tilde{n}\underline{I}_{\tilde{n}}}{\delta}\right] - \left[v(\underline{I}_n, n) - \frac{n\underline{I}_n}{\delta}\right]\right\} = \frac{1}{\delta}[v_I(\underline{I}_{\tilde{n}}, \tilde{n})\underline{I}_{\tilde{n}} - v_I(\underline{I}_n, n)\underline{I}_n]$$

and, using the Lagrange Residual of the Taylor series,

$$v_I(\underline{I}_{\tilde{n}}, \tilde{n})\underline{I}_{\tilde{n}} - v_I(\underline{I}_n, n)\underline{I}_n = [v_{I,I}(\zeta,\xi)\zeta + v_I(\zeta,\xi)]\,(\underline{I}_{\tilde{n}} - \underline{I}_n) + v_{I,n}(\zeta,\xi)\zeta(\tilde{n} - n)$$

where $\zeta = (1-\theta)\underline{I}_{\tilde{n}} + \theta\underline{I}_n$ and $\xi = (1-\theta)\tilde{n} + \theta n$ with $\theta \in]0,1[$. If $v_{I,I}$ is sufficiently negative the r.h.s. is negative which proves our claim.

Consider now the effect of δ on the optimal investment $\underline{I}^*$. If n^* were a continuous variable, then equation (11) above immediately would imply that whenever an increase of δ induces a larger n^* then $\underline{I}^*$ might decrease. However, when n changes with unitary increments and δ is in the $[0,1]$ range, the r.h.s. of (11) must increase when n^* increases. In other words, if the increase of δ is not large enough to affect n^*, then necessarily $\underline{I}^*$ must increase with δ. Increases of the discount factor δ are associated with possibly infrequent and (relatively) small reductions of $\underline{I}^*$ when n^* "jumps up" and more frequent and (relatively) large increases $\underline{I}^*$ when n^* remains constant. This follows from the observation that, for the same change $\Delta\delta$ of δ, the (absolute value of the) change of the r.h.s. in (11) is smaller when n^* increases than when it remains constant.

Q.E.D.

Proof of Proposition 3

The supplier's problem (13) in Subsection 4.4 above can be rewritten as

$$\begin{array}{ll} \max\limits_{\underline{I}} & [v(\underline{I},1) - \underline{I} - K]\frac{1}{1-\delta} \\ s.t. & [v(\underline{I},1) - \underline{I} - K]\frac{1}{1-\delta} \geq \underline{I}/\delta \quad (IC_s) \end{array}$$

or

$$\begin{array}{ll} \max\limits_{\underline{I}} & [v(\underline{I},1) - \underline{I} - K]\frac{1}{1-\delta} \\ s.t. & [v(\underline{I},1) - \frac{\underline{I}}{\delta} - K]\frac{1}{1-\delta} \geq 0. \end{array} \tag{18}$$

Given the definition of I^* in (15) above we can distinguish two possible cases. The first case is such that

$$[v(I^*,1) - \frac{I^*}{\delta} - K] \geq 0, \tag{19}$$

in which case $I^*_S = I^*$ and an increase of the discount factor δ is not associated with any change in the optimal level of investment I^*_S.

The second case is such that

$$[v(I^*,1) - \frac{I^*}{\delta} - K] < 0. \tag{20}$$

In this case $I^*_S = I_S$ where I_S is defined by

$$[v(I_S,1) - \frac{I_S}{\delta} - K] = 0. \tag{21}$$

From (21) given (14) above we have that

$$\frac{dI_S}{d\delta} = -\frac{I_S + \left[p^e(1) - p^e(N) - k\dfrac{N-1}{N}\right]}{\delta^2 \left(v'(I_S, 1) - \dfrac{1}{\delta}\right)}. \tag{22}$$

Consider first the numerator of (22). Clearly a necessary condition for the buyer to consider a deviation at t_4 that opens the auction to $\tilde{n} = N$ sellers is that the expected reduction in the price due to opening the auction, $p(1) - p^e(N)$, exceeds the expected cost of asking one of the $(N-1)$ sellers that did not participate in the development stage to produce the commissioned part, $k(N-1)/N$, that is

$$\left[p^e(1) - p^e(N) - k\frac{N-1}{N}\right] > 0$$

In the other case the (IC_b) constraint would not be binding.

Consider now the denominator of (22). We need to identify the sign of $[v'(I_S, 1) - \frac{1}{\delta}]$. Denote $\hat{I}$ the value of $\underline{I}$ such that

$$v'(\hat{I}, 1) = \frac{1}{\delta},$$

that is the value of $\underline{I}$ that maximises the function $[v(I_S, 1) - \frac{I_S}{\delta}]$. Notice also that the strict concavity of $v(\cdot, 1)$ implies that equation (21) or

$$[v(I_S, 1) - \frac{I_S}{\delta}] = K$$

has two solutions whenever $I_S \neq \hat{I}$. Denote these solutions I_S^1 and I_S^2 with $I_S^1 < \hat{I} < I_S^2$. The seller will choose the investment $I_S^* = I_S^i$, $i \in \{1, 2\}$ that maximises $[v(I_S^*, 1) - I_S^*]$.

We can then conclude that necessarily

$$I_S^2 < I^*. \tag{23}$$

Assume by way of contradiction that this is not the case, that is $I_S^2 > I^*$. Since the seller's problem is such that the (21) holds then

$$[v(I_S^2, 1) - \frac{I_S^2}{\delta}] = K$$

and from (20) above

$$[v(I^*, 1) - \frac{I^*}{\delta}] < K,$$

that is

$$[v(I_S^2, 1) - v(I^*, 1)] > [\frac{I_S^2}{\delta} - \frac{I^*}{\delta}] \tag{24}$$

while from the definition of I^* we have that

$$[v(I^*,1) - I^*] > [v(I_S^2,1) - I_S^2]$$

or

$$[v(I_S^2,1) - v(I^*,1)] < [I_S^2 - I^*].. \tag{25}$$

Inequalities (24) and (25) then imply

$$[I_S^2 - I^*] > [\frac{I_S^2}{\delta} - \frac{I^*}{\delta}]$$

which if $I_S^2 > I^*$ contradicts $\delta < 1$.

We therefore conclude from the definition of I^*, the fact that $I_S^1 < I_S^2 < I^*$ and the strict concavity of $v(\cdot,1)$ that the seller will choose $I_S^* = I_S^2$. Since $\hat{I} < I_S^2$ and $v'(\cdot,1)$ is a decreasing function we then have

$$v'(I_S^2,1) < v'(\hat{I},1) = \frac{1}{\delta},$$

which implies

$$\frac{dI_S}{d\delta} = -\frac{I_S + \left[p^e(1) - p^e(N) - k\dfrac{N-1}{N}\right]}{\delta^2\left(v'(I_S,1) - \dfrac{1}{\delta}\right)} > 0.$$

This concludes the proof of Proposition 3.

Q.E.D.

Suppliers' Market Power ($n > 1$)

Consider now the case where a group of $n > 1$ suppliers approach the buyer for procurement and propose a level of investment $\underline{I}$ in exchange of an ex-ante payments w. When it comes to production the buyer has the possibility to exploit the best blueprint procured by the n suppliers and run an auction with more, possibly all N suppliers that identifies an (expected) price $p^e(N)$. As with $n = 1$ the suppliers will optimally set w so that the (IC_b) binds, that is

$$w = \frac{1}{n}\left[v(\underline{I},n) - (v_0 - Nw')\right] + \frac{1}{\delta n}(1-\delta)k\frac{N-n}{N} - \frac{1}{\delta n}(p^e(n) - p^e(N)). \tag{26}$$

We focus here on the case in which the (IC_s) constraint does not bind. Substituting (26) in the suppliers' expected-discounted profit, the optimal level of investment $\underline{I}^*$ must satisfy the following condition

$$v'(\underline{I}^*,n) = n. \tag{27}$$

This clearly shows that if, when δ changes, the number of suppliers n does not change, as we observe in the data for high-tech products, then the $\underline{I}^*$ does not change either. This is clearly different from the case where the buyer has the bargaining power because, see Proposition 4 above, there we see that if n does not change, then necessarily an increase of δ must induce an increase in $\underline{I}^*$. It is also immediate to see from (27) above that n and $\underline{I}^*$ are negatively related.

Bundling Development and Production

The relational contract that we have considered in the main text contemplates bundling development and production and is motivated by the evidence in our industry. Substituting the supplier's binding incentive constraint, the associated buyer's payoff is

$$\left[v(\underline{I}, n) - n\frac{\underline{I}}{\delta} - \theta^e_{(1)}(n)\right]\frac{1}{1-\delta}.$$

The buyer and the suppliers may in principle agree to rely on a different relational contract where $n' \geq 1$ suppliers develop n' possibly different blueprints and competition for production involves all the N suppliers. Such type of procurement would allow to minimize the cost of production but would involve incurring the adjustment cost k.

Considering that the $N - n'$ suppliers excluded from development would be requested to pay an ex-ante participation fee w', similarly as to w for those developing, the buyer's objective function can be written as,

$$\left[v(\underline{I}', n') - n'\frac{\underline{I}'}{\delta} - \theta^e_{(1)}(N) - E(k)(1 - n'\beta(N))\right]\frac{1}{1-\delta},$$

where the expected cost of adjustment $E(k)$ is multiplied by the probability $(1 - n'\beta(N))$ that the producing most efficient supplier did not develop its blueprint.[43] Maximizing this objective with respect to n' the buyer faces a trade-off. On one hand fewer developing suppliers (that is lower n') avoid the duplication of investment costs (the second term in the parenthesis). On the other hand, this increases the probability of facing adjustment costs. As it can be seen, this trade-off (and the associated one on the optimal choice of I), is similar to that with bundling. Here the fewer developing suppliers imply a higher adjustment cost $E(k)\beta(N)$, with bundling they imply a higher production cost $\theta^e_{(1)}(n)$. Hence, whether at the optimum the buyer employs more or less suppliers at the developing stage with unbundling also depends on these different costs.

Considering that the two relational contracts may be associated with different levels of investment I and I', bundling dominates unbundling for the buyer if the following is satisfied,

$$E(k)(1 - n'\beta(N)) + \left[\theta^e_{(1)}(n) - \theta^e_{(1)}(N)\right] \geq \left[v(\underline{I}, n) - \frac{n\underline{I}}{\delta}\right] - \left[v(\underline{I}', n') - \frac{n'\underline{I}'}{\delta}\right]. \quad (28)$$

[43] We are not allowing the relational contract to be conditioned on the ex post realization of k because adjustment costs are typically private information of the parties, which would make the relational contract unrealistically complex.

The left hand side indicates the production-adjustment cost of unbundling. The two terms in the right hand side reflect the fact that two relational contracts may be associated with different levels of investment. Even if this is not the case, employing fewer developing firms allows the buyer to save on duplication costs here captured by the second terms in each parenthesis. What matter to our purposes, however, is that if $E(k)$ is large, then condition (28) implies the buyer prefers to bundle development and the possibility to produce.

Note that the cost of developing a blueprint is unrelated to the cost of developing a production technology based on a particular blueprint, including specific labor skills and expensive tools. The adjustment costs k may therefore be substantially higher than those of developing the blueprint. For example, the development cost for a front end module may be very small compared to the adjustment cost of producing it. Also, besides the cost of instructing the producing firm to use another firm's blueprint and to delay production to do so, the adjustment cost k may include as well the cost of managing the free riding problem and the conflicting incentives of the developer and the producer under unbundling. For example, when a firm i wins the production contract but did not develop the blueprint used for production, he can claim that ensuing problems with production follow from poor blueprint design rather than little care in adapting it in production.

Finally, two further considerations are in order. First, a relational contract may in principle condition the intensity of competition on the realization of k. However, this possibility is precluded by the fact that, realistically, only the buyer has a clear idea of the effective realization of the adjustment cost k that she will have to bear. Second, for some products the expected adjustment cost $E(k)$ may not be very high, and the buyer and the sellers may agree on a relational contract that explicitly relies on a number of competing suppliers at production $\tilde{n}$ larger than n, that at the investment stage, e.g. in a ratio two to one. Although the model would be different from the one studied here, the main results would qualitatively hold in this case too, as long as $\tilde{n} < N$. In this case in fact, we can identify conditions such that an increase in δ may now reflect into higher investment, larger n and $\tilde{n}$. The latter case is further discussed in the next appendix on multiple sourcing.

More suppliers in series production (multiple sourcing)

The management literature regards "supply assurance" as a crucial motive behind multiple-sourcing, that is, simultaneously procuring an input from different suppliers. The buyer hedges against the risk that her assembly line is brought to an expensive halt because the single supplier is not forthcoming with the parts at the right time or in the required quantity.[44] On the other hand, Riordan and Sappington (1989) and Rogerson (1989) stressed early on that, by reducing suppliers' production rents, second sourcing may undermine incentives for R&D.

In our environment, an adverse event (observable) may take place with probability α, in which case the unique supplier would be able to procure just a fraction $1-\gamma$ of the

[44] See Yu, Zeng, and Zhao (2009) or Wang, Gilland, and Tomlin (2010).

required production. Facing this risk of incomplete procurement—the costs of which we do not explicitly model, for simplicity—dual-sourcing and two production contracts may be preferable to single-sourcing. The first-source contract exhausts the entire production with probability $1-\alpha$. With complementary probability α the adverse event realizes and the first-source contract will only provide the fraction $1-\gamma$ of production. The second-source contract, under which the complementary fraction γ is supplied, will be executed in this case.

We mainly focus here on the case where the buyer designs the procurement contract. Since the buyer will never allocate the two contracts to the same supplier, dual-sourcing corresponds here to a multi-unit auction where firms are not allowed to win both contracts and are thus interested in winning just one of the two. With at least three competing suppliers, the buyer's selection mechanism is assumed to be a uniform-price auction (which is efficient here and involves truthful bidding).

With dual-sourcing the buyer pays more for production, since the price paid to the two winners of the first- and second-source contracts is the production cost $\theta^e_{(3)}(n)$ of the third- rather than the second-most efficient firm as in the case of single sourcing (Section 4.3). Yet dual-sourcing almost surely guarantees complete production even in the case the adverse event is realized. The higher price paid by the buyer translates into higher expected information rents to suppliers. To see this, note that from the analysis above the expected rent with single-sourcing is $\beta(n)\pi(n)(1-\alpha\gamma)$. With dual-sourcing, it is instead

$$\beta(n)\pi_1(n)(1-\alpha\gamma)+\tilde{\beta}(n)\pi_2(n)\alpha\gamma$$

, where $\beta(n)$ and $\tilde{\beta}(n)$ are respectively the probabilities of being the most efficient and the second-most efficient supplier—both equal to $(1/n)$—with associated rents $\pi_1(n)$ and $\pi_2(n)$.[45] Since $\pi_1(n)\geq\pi(n)$, dual-sourcing guarantees a larger expected rent to suppliers. With an argument similar to that in Section 4.3, we obtain:

Proposition 4 *Assume the function $v(\cdot,n)$ is sufficiently concave. If δ has an effect on the type of procurement, then an increase in δ induces the buyer to switch from single-sourcing to dual-sourcing.*

Proof: From the binding suppliers' incentive compatibility constraint, as in (5), and coherently with w being paid *ex ante* with respect to production, whether a producer delivers full production or not, we obtain an equivalent optimal procurement program $\mathcal{P}_d$ with dual-sourcing and associated per-period payoff for the buyer:

$$H_d(\underline{I}^*_d,n^*_d)=v(\underline{I}^*_d,n^*_d)-n^*_d\frac{\underline{I}^*_d}{\delta}-(1-\alpha\gamma)\theta^e_{(1)}(n^*_d)-\alpha\gamma\theta^e_{(2)}(n^*_d).$$

We now compare dual-sourcing to single-sourcing, the latter being now associated

[45] To simplify notation we assume that a firm i that procures a fraction of total (unitary) production faces a production cost which is the corresponding fraction of its cost θ_i. Then we have $\pi_1(n)=\theta^e_{(3)}(n)-\theta^e_{(1)}(n)\geq\pi_2(n)=\theta^e_{(3)}(n)-\theta^e_{(2)}(n)\geq 0$.

with a buyer's expected (per-period) payoff:

$$H(\underline{I}^*, n^*) = (1-\alpha\gamma)v(\underline{I}^*, n^*) - n^*\frac{\underline{I}^*}{\delta} - (1-\alpha\gamma)\theta^e_{(1)}(n^*).$$

where, as usual, $\underline{I}^*$ denotes the optimal investment under single-sourcing and n^* the number of developers.

To make the analysis interesting so that a change δ can have an impact on the type of sourcing, we assume that (i) if the buyer can only procure nil investment, as when $\delta = 0$, then it is optimal to procure with single-sourcing, which formally requires

$$H_d(0, N) = v_0 - (1-\alpha\gamma)\theta^e_{(1)}(N) - \alpha\gamma\theta^e_{(2)}(N) < H(0, N) = (1-\alpha\gamma)v_0 - (1-\alpha\gamma)\theta^e_{(1)}(N)$$

or equivalently

$$v_0 < \theta^e_{(2)}(N);$$

(ii) if investment is perfectly contractible, as when $\delta = 1$, then it is optimal to procure with dual sourcing, which formally requires:

$$H_d(\hat{\underline{I}}_d, \hat{n}_d) = v(\hat{\underline{I}}_d, \hat{n}_d) - \hat{n}_d\hat{\underline{I}}_d - (1-\alpha\gamma)\theta^e_{(1)}(\hat{n}_d) - \alpha\gamma\theta^e_{(2)}(\hat{n}_d) >$$

$$> H(\hat{\underline{I}}, \hat{n}) = (1-\alpha\gamma)v(\hat{\underline{I}}, \hat{n}) - \hat{n}\hat{\underline{I}} - (1-\alpha\gamma)\theta^e_{(1)}(\hat{n})$$

where the variables n and I are the optimal choices with contractibility. When $\hat{n}_d = \hat{n} = \tilde{n}$ this is equivalent to:

$$\left[v(\hat{\underline{I}}_d, \tilde{n}) - \tilde{n}\hat{\underline{I}}_d - \left(v(\hat{\underline{I}}, \tilde{n}) - \tilde{n}\hat{\underline{I}}\right)\right] + \alpha\gamma\left[v(\hat{\underline{I}}) - \theta^e_{(2)}(\tilde{n})\right] > 0$$

where the first square bracket is positive and the condition is then implied by:

$$v(\hat{\underline{I}}, \tilde{n}) > \theta^e_{(2)}(\tilde{n}).$$

These two assumptions are consistent with the facts that if procured investment is nil, the value of complete procurement is relatively low and the buyer is ready to minimize its cost with single-sourcing. On the other hand, when the buyer wants to procure a very large investment, then risking incomplete procurement is very costly and dual-sourcing should be optimal.

Now notice first that if the investment is the same $\underline{I}^* = \underline{I}^*_d = \hat{I}$, for any given δ the buyer, when indifferent between single- and dual-sourcing, will choose a larger number of developing firms under dual-sourcing than under single-sourcing. In other words:

$$H_d(\hat{I}, n^*_d) = H(\hat{I}, n^*)$$

implies:

$$n^*_d > n^*.$$

With dual-sourcing, the buyer can leverage on the larger expected rent for suppliers, thus affording more competing firms.

Notice also that for any given δ and equal number of developing firms $n_d^* = n^* = \hat{n}$, the optimal target investment under dual- and single-sourcing are such that:

$$\underline{I}_d^* > \underline{I}^*$$

because the optimal target investment under single-sourcing is such that:

$$v_I(\underline{I}^*, \hat{n}) = \frac{\hat{n}}{\delta(1-\alpha\gamma)}$$

while the optimal target investment under single-sourcing is given by:

$$v'(\underline{I}_d^*, \hat{n}) = \hat{n}\frac{1}{\delta}.$$

Following the same steps as in the proof of Proposition 2, it now follows immediately that for any given δ if the function $v(\cdot, n)$ is sufficiently concave when the buyer is indifferent between single- and dual-sourcing: $H_d(\underline{I}_d^*, n_d^*) = H(\underline{I}^*, n^*)$ hence we have $n_d^* \underline{I}_d^* > n^* \underline{I}^*$

Moreover, the envelope theorem implies that, as in Section 4.2 above, the effects of δ on the optimal value of the buyer's per-period payoff under both dual- and single-sourcing are:

$$\frac{\partial H_d}{\partial \delta} = \frac{(n_d^* \underline{I}_d^*)}{\delta^2}, \qquad \frac{\partial H}{\partial \delta} = \frac{(n^* \underline{I}^*)}{\delta^2} \tag{29}$$

If $v(\cdot, n)$ is concave enough, $\frac{\partial H_d}{\partial \delta} > \frac{\partial H}{\partial \delta}$, and since $H_d(0, N) < H(0, N)$ and $H_d(\hat{\underline{I}}_d, \hat{n}_d) > H(\hat{\underline{I}}, \hat{n})$, by continuity there is a threshold for δ such that $H = H_d$. We can then conclude that when the function $v(\cdot, n)$ is sufficiently concave, if δ increases the buyer moves from optimally choosing single-sourcing to choosing dual-sourcing: dual-sourcing is more likely the higher is the level of δ. This concludes the proof.

Q.E.D.

Although the thresholds for concavity of Proposition 4 and of Proposition 2 are not the same, the result is based on a similar mechanism. First, dual-sourcing guarantees a larger rent to suppliers than single-sourcing. Hence, as in the model of the main test, the "slackness" in suppliers' incentive compatibility translates into a larger optimal number of developing suppliers n_d^* *and* higher investment $\underline{I}_d^*$ (d denotes dual-sourcing) compared with single-sourcing, if the function $v(\cdot, n)$ is sufficiently concave. Second, the higher investment and larger number of suppliers imply that the actual cost of development with dual-sourcing $(n_d^* \underline{I}_d^*)/\delta$ is higher than that with single-sourcing. This finally implies that an increase of δ benefits the buyer (in reducing the actual cost of development) more with dual-sourcing than with single-sourcing, so that if a larger δ has an effect at all, it induces the buyer to move from single-sourcing to dual-sourcing.

When procurement design is in the hands of suppliers, dual-sourcing seems less relevant and natural. If the buyer's value significantly reduces in case of production halt, a “main” supplier with bargaining power may involve one (or more) additional supplier with the type of step-in contract described above. This sub-contract would allow to increase the buyer’s expected value, which the main supplier can then extract. At the same time, the difficulty is that, in addition to his own incentives, the main supplier must also guarantee the sub-contractors’ incentive compatibility constraints with appropriate transfers. The optimality of subcontracting very much depends on this subtle comparison and, what is more for our purposes, the effect of a larger δ is ambiguous.