Relational Contracts, Competition and Innovation:

Theory and Evidence from German Car Manufacturers*

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July 2017

Abstract

Using unique data from buyer-supplier relationships in the German automotive industry, we unveil a puzzle by which more trust in a relationship is associated with higher idiosyncratic investment, but also more competition. We develop a theoretical model of repeated procurement with non-contractible, buyer-specific investments rationalizing both observations. Against the idea that competition erodes rents needed to build trust and sustain relationships, we infer that trust and competition tend to go hand in hand. In our setting trust and rents from reduced supplier competition behave like substitutes, rather than complements as typically understood.

JEL classification: D86, D22, L22, L62.

Keywords: Trust, Hold-up Problem, Competition, Innovation, Specific investment, Procurement, Relational contracts, Management practices, Suppliers, Car manufacturers, German automotive industry.

*We acknowledge the generous hospitality of Studienzentrum Gerzensee, where substantive parts of the research work were completed. We greatly benefitted from comments by seminar participants at Bologna, Columbia, Berlin, Copenhagen, Edinburgh, ESSET (Gerzensee), Frankfurt (CEPR Workshop on Incentives and Organizations), Hebrew (CEPR IO-conference), 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 Bolton, Jeff Butler, Andrew Clausen, Chaim Fershtman, Maria Guadalupe, Pierre-Olivier Gourinchas, Shaul Lach, Bentley McLeod, John H. Moore, Hodaka Morita, Rob Porter, Wilhelm Rall, Klaus Schmidt, André Stenzel, Jonathan Thomas, Ina Taneva, Peter Vida, Luis Vasconcelos and Luigi Zingales, and from detailed comments by Liran Einav, Bob Gibbons, Rocco Macchiavello and Giorgio Zanarone. Financial support from the Deutsche Forschungsgemeinschaft (SFB-TR-15) is gratefully acknowledged.

1 Introduction

Informal arrangements that are not enforceable 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 partner(s) in the interaction are not short run oriented and thus do not behave opportunistically, but incorporate the potential future effects of their action into their current decisions.

Such beliefs facilitate the implementation of relational contracts in situations where standard legal contracts are simply not enforceable. 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. In business relationships involving repeated sequences of exchanges, trust-based relational contracts are considered to be efficient governance instruments for non-contractible dimensions. A typical setting is the relationship between suppliers and buyers.

An interesting example of a trust-based relationship involving one buyer and several suppliers is the procurement of parts for complex products, such as automobiles. In this market, relational contracting in various forms was—and is—pervasive in both the Japanese and the German automotive industries, which are among the most influential and innovative in the world. In both countries, suppliers are typically involved in long-term relationships with their buyers, the automotive producers, and—in contrast to the U.S.—undertake the majority of the innovative R&D investment embodied in any new car model.

The long-term trust-based relationships in Germany are particularly interesting because of the changes introduced by Ignacio Lopez. In 1993 he was poached away by VW from GM as chief procurer with the express mission to implement confrontational arm's-length procurement contracting, in order to extract rents from upstream suppliers and restore VW's profitability. It essentially consisted of expropriating the supplier's intellectual property rights (IPR hereafter) embodied in a blueprint, by using it without compensation to procure worldwide for production.[1] Driven by the same quest for higher

[1]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 the Lopez's case is found *here*.

short run profitability, some other, but not all, automotive producers followed suit and adopted aggressive procurement strategies, which caused considerable turbulence in industry relations. The long shadow of this turbulence prompted the industry association to commission an unusually detailed survey on the trust relationship between first-tier suppliers and their buyers, the automotive producers. This paper is based on this survey. Our evidence thus reflects a rather unique historical episode involving intra-industry variation in trust across buyer-supplier relationships.

Our first empirical finding is that higher trust levels in a relational contract are associated with more buyer-specific investment by suppliers. This is in line with existing theoretical research, but we are among the first to provide real-life—as opposed to experimental—evidence of this effect. The congruence with established theory supports the validity of the data in the face of our second, rather more puzzling finding. One might expect more competition among suppliers to be detrimental to the trust relationship with a given buyer. Instead, we find that 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 gadget for a new car model, and with more frequent co-sourcing in the production phase of a part, that is, more than one supplier producing in parallel.

Especially in view of the established explanation of the first finding, the second finding could be regarded as a puzzle, as we are aware of no immediate explanation for it in the literature to date. We therefore develop our preferred explanation of that puzzle, within a model of relationship-specific investment in a relational contracting setting that reflects the environment from which we have gathered the empirical evidence. We use the remainder of the paper to discuss alternative explanations of this puzzling relationship and we argue in favor of our proposed explanation.[2]

In our model, a buyer repeatedly procures a product. This involves the development of a blueprint requiring buyer-specific and non-contractible R&D investment by 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

[2] In this vein, our model is not developed in order to be tested, but to serve as a hopefully unique explanation of the empirical facts. With this we follow Popper (1935)'s claim that a theory should be held true until refuted by a better one. We think of this procedure as a *neo-popperian* approach to establishing causal structure.

costs, which are unknown to the buyer. At the start of the development phase, the buyer chooses the amount of investment she desires from the typical supplier, then invites one or more of them to invest in R&D and develop a blueprint for the part in question, and selects a blueprint. 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. Non-contractible on the buyer side is the promise to select suppliers for production from the set of suppliers invited to the development contest rather than from outside the set. On the supplier side the R&D investment towards the blueprint is non-contractible. A deviation by the buyer consists of opening competition for the production contract to all potential suppliers independently of whether they undertook any investment. A deviation by the typical supplier consists of insufficient investment into developing a blueprint as required by the buyer. 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 for future blueprints.

In equilibrium the buyer maximises her expected profits by ensuring that the incentive constraints on both sides of the market are not violated and inducing future cooperation. In doing so she restricts herself to selecting for development and production a strict subset of suppliers from the total set. 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, the participants' belief that the future involves a co-operative arrangement—allows the buyer to increase both the investment by the typical supplier and 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 larger value of future interactions due to increased trust. Hence, in this interpretation, *trust and competition tend to go hand in hand.*

Towards interpreting this main result, it is critical that in our setting the buyer honors her incentive constraint by limiting competition for the production contract to the suppliers that participated in the development of the product, undertook relationship-specific investments, and did not underinvest in the past. 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 relationship-specific investment. This incentive effect would disappear if, in line with Lopez's strategy, competition for the production contract were to be open to all suppliers including those that had not undertaken relationship-specific investments.

The structure and the results of the model are reflected well in our data. The constraints essential for our theoretical analysis are documented in case study evidence collected in 2005/06—including their historical violations. The questionnaire survey data collected in 2007/08 involved all German automotive producers and key first-tier suppliers. They represent what can be interpreted as a set of relational contracts that, as a long-term consequence of the Lopez affair, resulted in significant variation in the levels of trust across individual supplier-buyer relationships.

We use this evidence to address competing explanations of the relationships we have found—including potential reverse causality. In particular we are able to reject a central competing hypothesis by which increased competition drives our empirical results. Furthermore, higher investment cannot jointly explain higher trust and more competition. While we cannot completely rule out the hypothesis that increased investment may imply higher trust, we could not find an alternative to our preferred explanation on the ensuing positive relationship between trust and competition.

Our study reflects the specifics of a country and an important sector. Yet it also provides insights that are valid in many other procurement environments involving complex parts for complex products. Key examples are parts for the production of airplanes, trains, defense, and aerospace gadgets.[3]

The remainder of the paper is organized as follows. In the ensuing Section 2 we review the pertinent theoretical, experimental and empirical literatures. Section 3 contains our two central empirical relationships. In Section 4 we develop our preferred explanation of these relationships within a theoretical model. In Section 5 we propose a number of alternative explanations of the empirical relationships we found, and address them in turn. We conclude in Section 6. Details involving the collection and the description of our empirical material, as well as proofs of our propositions, are relegated to the Empirical and Theoretical Appendices, respectively.

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

2 Literature review

There is a large literature looking 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 the classic Fisher-GM case or Asanuma (1989)'s case-based description of upstream supplier-buyer relationships in the Japanese automotive industry as examples. Malcomson (2012) uses the same case to motivate his survey of the relational contracting literature. Our evidence is in the same spirit, but based on a large-scale questionnaire survey rather than on specific case studies.

Central to our analysis is 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 with small variants in more recent contributions to the literature on relational contracting.[4]

In the recent theoretical literature on relational contracts, the discount factor is also regarded as the best indicator of trust in that environment. Kvaloy and Olsen (2009), in their model of relational contracts with endogenous verification, argue that the discount factor is 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.[5] In our relational contracting model, we also interpret the discount factor as an indicator of the level of trust.

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 purely material

[4] See MacLeod (2007) and Malcomson (2012) for a summary of this literature.

[5] Accordingly, Bodoh-Creed (2015) 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 (2014) 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.

incentives remains common in the marketing and strategy literatures, further justifying its use in the survey questions and throughout this paper.

Because this specific interpretation 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.[6]

For what concerns the theoretical relationship between relational contracts and competition, our paper 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.[7] They highlight a trade-off between reputational forces and collusion among agents: restricting competition to a smaller set of agents and shortening contract duration may help limiting moral hazard, but at the risk of inducing collusion among these agents against the principal. Our theoretical analysis, however, deals with a different stage game where suppliers invest in non-contractible R&D before knowing whether they will be selected to produce the good, and focuses on different economic questions.

To our knowledge, the only other empirical analysis of the relationship between trust and competition is 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 induces higher levels of trust. As in Brown, Falk, and Fehr (2012)'s experimental study, competition acts as a disciplining device that induces the reliability of service provision, which in turn increases its trustworthiness. Our reasoning is the opposite: the presence of high trust in the relationship allows the buyer to introduce competition among suppliers.[8]

In general, the existing literature has focused on the negative effect of competition on trust-based relationships.[9] For example, McMillan and Woodrooff (1999) show em-

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

[7]See also Board (2011) and Andrews and Barron (2016) who however focus more on dynamics rather than on competition.

[8]The tradeoff between competition and trust we derive in our model is similar, in spirit, to the tradeoff in the incomplete-contract model of Rajan and Zingales (1998). See also the literature on the relationship between competition and the hold-up problem (Cole, Mailath, and Postlewaite, 2001a,b; Peters and Siow, 2002; Peters, 2007; Felli and Roberts, 2016).

[9]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

pirically 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. Helper and Levine (1992) argue that arm's-length competitive supply relations are good at protecting downstream oligopolistic rents from suppliers' attempts at appropriating them, but the increase in competition among automakers—that is entry by Japanese car producers in the US market—forced US manufacturers to move towards more efficient trust-based supply relationships.

More recently, Macchiavello and Morjaria (2015a) study the effects of competition between coffee mills in Rwanda on the prevalence of relational contracts with coffee farmers. Their theoretical framework predicts that competition under certain circumstances undermines relational contracts—they either become less efficient than under monopoly, or even unsustainable. Empirically, they find evidence that exogenous variation in (downstream) competition between mills reduces the occurrence of relational contracting and leads to inefficient utilization of resources. Our paper is highly complementary to this approach. In our industry setting, buyers are able to strategically induce (upstream) competition among suppliers. Competition is not exogenously given, but instead the choice variable whose outcome we are interested in explaining. We show that the suppliers' trust is positively correlated with the level of competition that the buyer induces.

Our analysis is also related to the growing literature on managerial practice in manufacturing firms, and in particular to that relying on relational contracts.[10] 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.[11] Helper and Henderson (2014) make a strong case for relational contracts as the crucial managerial practice to explain the ability of Toyota and other Japanese car manufacturers to largely outcompete US carmakers in the 80s and 90s.

Within this literature, Aral, Bakos, and Brynjolfsson (2017) analyze theoretically

competitive, relationships. See also Sako (1992), MacDuffie and Helper (1997), and references therein.

[10]See the surveys by Bloom, Lemos, Sadun, Scur, and Van Reenen (2014) and Gibbons and Henderson (2012b).

[11]For a quantification of the value of relationships see Macchiavello and Morjaria (2015b) and references therein. See also Gil and Zanarone (2014) for a survey of the empirical papers that provide evidence of relational contracts.

and empirically how firms source IT hardware and services in different countries. They show that the specific type of IT adopted by a firm has consequences in terms of the number of its suppliers. When vendor-specific IT leads to fewer suppliers, repeated relationships become key to the governance of the supply chain. Specifically, if supplier's relationship-specific investment increases, the number of suppliers decreases, and firms engage in more repeated relationships with those suppliers. Our analysis differs in the sense that the availability of a measure of trust allows us to identify both theoretically and empirically the role of trust in long-term relationships. In particular, we are able to directly assess the interaction between trust, competition and investment with very detailed data on bilateral relationships.

Finally, our paper is related to the literature on the procurement of innovation.[12] The focus in that literature is typically on the optimal design of static mechanisms to elicit innovation, like auctions or contests, for public buyers. We focus instead on how the dynamic relationship between a private buyer and his regular suppliers governs, through the shadow of the future, the supply of multiple, sequential and typically incremental innovations (new blueprints).

3 Trust, investment and competition: evidence

Our empirical evidence was collected within a detailed questionnaire survey on the relationships between automotive manufacturers in the German automotive industry and their first-tier suppliers, conducted under the auspices of the German Association of Automotive Manufacturers (VDA) between the Fall of 2007 and the Summer of 2008.[13] 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. Accordingly, the main motivation for the study was to document the level of trust in specific supplier-buyer relationships without bias, and to develop ideas of how the long shadow of confrontation and mistrust could be

[12] See for instance Maurer and Scotchmer (2004) and Cabral, Cozzi, Denicolò, Zanza, and Spagnolo (2006) for surveys, and Che, Iossa, and Rey (2014) and Battacharya (2016) for recent contributions.

[13] The questionnaire survey was preceded by pilot case studies performed 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—essentially the same respondents. Müller, Stahl, and Wachtler (2008) summarise the results of these case studies. They present a very detailed view of the relationship between producers and their first-tier suppliers.

amended.

The study involved a collaborative effort at the association level. The preparation of the survey questions—including the alternatives for the respondents' answers—and the entire study was supervised by a steering committee nominated by the VDA chairmanship. All firms addressed had representatives in the VDA—which ensured fairly complete and truthful (anonymous) reporting. Supplier-buyer relationships were long term and involved several decades; this ensures that we can talk about repeated relationships.[14]

Each completed questionnaire explored trust in the relationship between a given supplier and a given buyer over the life cycle of a given part and thus included the responses of many individuals within the firm. The essential phases analyzed in this paper are buyer/model-unspecific *pre-development*, buyer/model-specific *development*, and *series production* of that specific part. For analytical reasons each part was assigned to one of four categories: both small and technologically unsophisticated *commodities*, small but *high tech components*, large but technologically unsophisticated *modules*, and both large and technologically sophisticated *systems*. The typical respondent was the manager in charge of the part in one of the phases.

An observation in our empirical analysis is defined as a given supplier's view on a given buyer's conduct with regard to a specific part; that is, the responses of supplier A assessing the procurement practices of buyer B concerning, say, sparkplugs (a commodity).[15] The procurement practices of buyer B concerning the electronic stability program (ESP) (a system) would then constitute a different observation. The survey is described in detail in the Empirical Appendix below. Here, we concentrate on our measure of trust, and on the basis of this we highlight the empirical relationships between trust and investment, and trust and competition in both development and production procurement.

[14]Among the observed buyer-supplier relationships in our sample, 61% have lasted longer than 15 years. Among the remaining, the average duration is 8.7 years. Given the annual introduction of new car models by each automotive producer, this would still cover at least 8 generations of car models. Only 1% of our part-specific observations stated a duration of the relationship of less than 4 years.

[15]This assessment typically includes the responses of many individuals in charge of specifics. We aggregate these responses. This mediates potential idiosyncrasies that may be involved in individual responses.

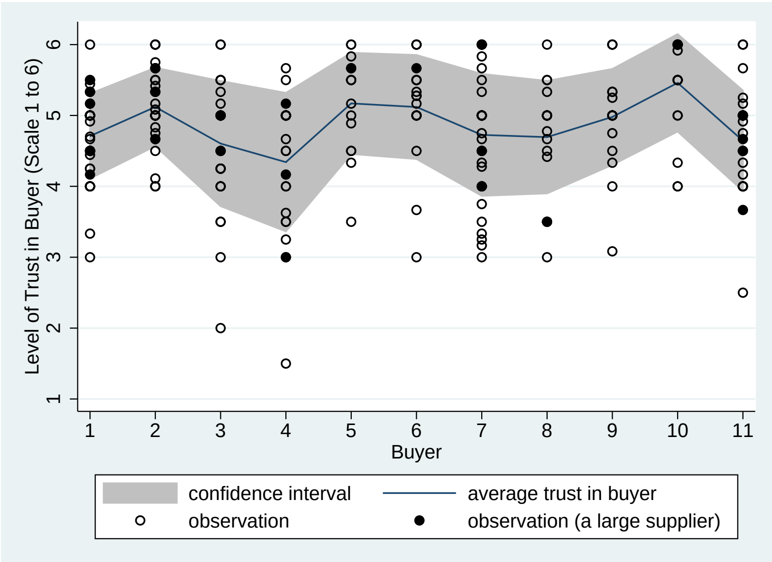
3.1 A measure of trust

Trust is a sensitive concept which has proven to be somewhat elusive to attempts at explanation and measurement. Our questionnaire provides us with the suppliers' assessment of trust associated with the provision of a particular part to a specific buyer. This assessment is provided for each of the three product life-cycle phases (pre-development, development and production). We take the average of the responses in each phase to obtain a measure that covers the entire relationship. It is important to notice that procurement officers are usually responsible for individual parts, or part groups, and therefore we expect to find (and do find) variation in buyer behavior even in dealings with a given supplier. Furthermore, procurement strategies should depend on the characteristics of the part in question. This observation is reflected by the descriptives in Figure 1 below.

In the survey, the individual in charge of a given part in a given phase was asked his evaluation of trust in the relationship with a given buyer (called OEM, i.e. original equipment manufacturer in the survey) as follows: *Please evaluate the importance of mutual trust between the supplier and OEM for the OEM's supplier selection.* Responses were given on a six-point scale from 1 (no relevance) to 6 (very important) for each stage—pre-development, development and series production. The issue of trust was central to the entire survey, and different measures were developed in an intensive discussion in the steering committee responsible for the survey design. Questions were formulated in terms of *importance of trust* rather than *trust* directly to avoid personalized responses. 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 with our chosen measure. Below, we explore the factors influencing our trust measure in detail (see Table 5). In summary, confrontational past behavior in line with the Lopez deviation (IPR conflicts, disregard of supplier IPR, price renegotiations) is highly detrimental to measured trust. As we will show, our trust measure is associated with significantly higher supplier investment. A central advantage of our measure is that the survey adjacently also asks about the role of other factors, especially price. This allows us to carry out an important robustness check in which we normalize our trust measure, see in particular the results in Tables

11 and 12 in the Appendix.

Our central measure of trust is the arithmetic mean of the suppliers' responses across the three pre-development, development and production phases of a specific part procured by a given buyer—in this way, the role of individual outliers is reduced and the assessment reflects the views of multiple individuals. The resulting variable is referred to below as the "trust index".[16]



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

Figure 1: Variation in the trust measure.

We report the suppliers' responses to our key question in Figure 1 above. It displays the variation in trust in our data. On the one hand, suppliers' trust overall differs substantially across buyers. This results from variations in the degree to which buyers emulated Lopez's procurement strategies. On the other hand, suppliers do not completely agree in their assessments of buyers, depending on the actual histories of interactions. To emphasize this important point, the solid black dots represent the responses by a large supplier in the survey. They show how the level of trust with respect to the same buyer can differ, reflecting different procurement strategies across (types of) parts.[17]

[16]We also ran the regressions below using the individual measures instead of their arithmetic mean. The results are qualitatively the same, though significance levels vary due to differences in the number of observations.

3.2 Trust and investment

The first empirical relationship we propose is that higher levels of trust are associated with more relationship-specific investment by suppliers.

Measuring relationship-specific investment poses a serious challenge. We do not observe this investment directly, but we observe an outcome variable highly correlated with it, namely the part-specific failure rate as specified by the supplier.[18]

Along these lines, 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 were interpreted as probabilities increasing from 0 to 100% in steps of 25%.[19] We carry out the following Fractional Probit specifications with robust standard errors:

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

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. The control variables include dummies for the degree of technological sophistication and size of the part as well as the interaction between the two dummies, and the supplier's revenues in 2007, as a proxy for the supplier's bargaining power.[20] With the controls, we capture product-related differences through the specification of both part complexity and size, and bargaining power-related supplier characteristics through supplier revenues. Here, as in all following specifications, standard errors are clustered at the level of buyer-seller pairs.

In Table 1 below we present two specifications with and without dummies for the

[17]Procurement officers at buyer firms are often responsible for certain parts or part groups. For a discussion of trust determinants, see Section 5 below.

[18]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).

[19]Self-reporting of problems may lead to under-reporting. To counter this, complete anonymity was guaranteed at the outset and upheld throughout the course of the study. In any case, we would *underestimate* the observed effect if more trust leads to a higher likelihood of admitting problems in the questionnaire.

[20]The dummy on the part's technological sophistication is 1 if the part is a high tech component or a system, while the dummy on the part's size is 1 if the part is a module or a system.

11 buyers.[21] The buyer fixed-effect controls for unobserved buyer specific features that may simultaneously affect trust positively and part-related failure rates negatively. In particular, it controls for the buyer's selection of suppliers including the suppliers' buyer-specific self-selection, if applicable at all, the buyer's complementary investment, as well as differences between the buyers' final products.

Variables	**Fractional-Probit**$^{\heartsuit}$	
trust index	**-.155****	**-.191****
	(0.044)	(0.018)
tech. Soph. (D)	.055	.026
	(.770)	(.890)
size of part (D)	**.656*****	**.675*****
	(.000)	(.000)
interaction	-.116	-.055
	(.728)	(.866)
supplier revenues	-.006	-.006
	(.457)	(.371)
const	-.558	-.162
	(0.131)	(0.703)
Buyer-FE (11)	**no**	**yes**
# observations	126	126

The table reports regression results for the following dependent variable: ♡ frequency of quality problems arising (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 1: Trust and investment proxied by quality issues: Fractional-probit results

Consistently with the literature we expect a negative coefficient for β. The likelihood of quality issues arising decreases in trust. The results in Table 1 show that higher levels of supplier trust are associated with significantly less frequent quality issues. The size of the coefficient is relevant from an economic perspective. Increasing trust by one standard deviation (0.79) coincides with a decrease in the probability of quality problems of 12% to 16,5%.

Including buyer dummies increases the strength of the central relationship. The buyer fixed effect could account for the buyer's selection of suppliers that are particularly competent in the production of the part in question, or for the buyer's supplier-specific complementary investment, that, if absent, may decrease both the supplier's trust and the quality of parts. In other words, in the absence of buyer fixed effects, the effect of

[21] We present more complex specifications with additional sets of fixed effects in Section 5.

trust on quality (via the suppliers' investment) is underestimated.

Our data give us a handle on an issue on which it is usually very hard to gain any traction. When trying to assess under-investment-related quality issues empirically 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 questionnaire is that responses are part-specific, so issue (a) can be easily addressed. The phrasing of the question addresses issue (b), as it was meant to include all of the development and production phases involving the part in question. In order to address issue (c), the possible complementary effort or skill on the part of buyers, we introduce a dummy for each of the eleven buyers in our regressions, that captures the buyer's effect on quality.

3.3 Trust and competition

The more surprising empirical relationships we have found are between trust and competition in pre-development, development, and series production. In all three phases, we observe the intensity of competition measured by the number of competing suppliers (in both development stages) or parallel producers (in series production).

One should emphasize the different character of supplier investments across the three stages: In pre-development, the earliest phase, investment by the supplier is not model- or even relationship-specific, but closer to research into technology. In other words, there is no possibility of hold-up on the part of the typical buyer.[22] The situation is very different at the development stage. Suppliers have to undertake substantial development investment to adjust their existing technology to the buyer's specific requirements which differ for each car model. A sensitive issue at this stage is that 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 firm. Furthermore, the supplier's IPRs, even when embodied in patents, are much less well protected than one might expect. In 31% of the development relationships, suppliers report that in the past buyers have passed on at least part of their IPRs to competitors without their consent.[23]

[22]An exception, to be discussed below, may arise when the supplier initiates a co-development with a particular buyer.

The dependent variable in our regressions is a count-variable. Therefore we report the results of Poisson regressions below with the dependent variable n_{ijs}, the number of competitors including supplier s involved in the pre-development and development phases, or the number of parallel suppliers in production, respectively, of part i supplied to buyer j.

Variables	**Pre-Dev.** ♠		**Dev.**♣		**Ser. Prod.**♡	
trust index	-.022	.001	**.163*****	**.203*****	**.149*****	**.137*****
	(.656)	(.991)	(.006)	(.003)	(.002)	(.023)
tech. Soph. (D)	-.120	-.110	**-.237****	**-.219****	**-.290*****	**-.306*****
	(.241)	(.257)	(.024)	(.034)	(.001)	(.000)
size of part (D)	**-.188***	-.104	.173	.209	**-.306*****	**-.290*****
	(.094)	(.381)	(.271)	(.129)	(.000)	(.000)
interaction	.199	.106	-.440	**-.475***	.182	.131
	(.283)	(.571)	(.152)	(.054)	(.272)	(.385)
supplier revenues	.002	.004	**.022*****	**.026*****	.005	.006
	(.550)	(.226)	(.000)	(.000)	(.267)	(.165)
const	.924	.553	-.542	-.964	-.402	-.526
	(.000)	(.081)	(.073)	(.015)	(.063)	(.084)
Buyer-FE (11)	**no**	**yes**	**no**	**yes**	**no**	**yes**
# observations	78	78	126	126	127	127
Pseudo-R^2	.004	.012	.043	.063	.023	.032

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; standard errors are clustered at the level of buyer-seller pairs; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 2: Trust and Competition: Poisson-regression results

Table 2 above presents our regressions. It shows the relationship between trust and the number of suppliers employed in the pre-development, development and the series production stages, respectively—each with controls for the type of part in question, the suppliers' yearly revenues as a proxy for their bargaining power resulting from size, as well as additional specifications including buyer fixed-effects.

In pre-development and development suppliers competitively undertake R&D investment. The buyer then chooses the winning blueprint(s)—and with it, the suppliers who produce that part. In production, the dependent variable is instead the number of

[23] 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).

suppliers that produce the part in parallel.

In the development phase, an increase of trust by one standard deviation is related to 0.13 additional suppliers, compared to the average of 1.54 suppliers involved in this stage. In the series production phase, the coefficients are similar in magnitude. An increase of the trust measure by one standard deviation is associated with 0.12 additional suppliers, relative to an average of 1.22 suppliers involved in that phase. As opposed to this, there is no empirically significant relationship between trust and the number of suppliers during pre-development.

In the ensuing Section 4, we provide a relational contracting model rationalizing the positive association of trust with investment, and with competition in the development and production phases.

4 A model of innovative supply 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, especially for the procurement of complex parts for complex products whenever the suppliers' R&D is an essential input into the final product.

4.1 Model elements

In each one of an infinite sequence of periods a buyer (referred to as "she" for distinction) 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 (referred to as "he" for distinction), and subsequently the production of the intermediate product. That investment is non-contractible. Its cost is sunk and normalized to I for I units of investment.

There are $N > 1$ firms capable of investing and supplying the intermediate product.[24] In case the buyer selects more than one supplier for its development, the suppliers invest independently and competitively. As investment I is buyer-specific, it has no value for buyers other than the one commissioning the intermediate product. The value to

[24]We ensured that $N > 1$ in the empirical part of our study.

the buyer of the final product with embedded investment I and developing firms n is $v(I, n)$, a function increasing in both arguments, strictly concave and satisfying Inada conditions. Although a strictly positive derivative v_n is not necessary for our results, when several firms develop a blueprint the buyer is less exposed to the risk that the developing process is overall unsuccessful. Moreover, the activities of any one of the developing firms often generate positive spillovers to other developers and the ultimate value to the buyer increases. In both cases, the marginal value of investment is also increasing in the number of firms, that is $v_{In} \geq 0$. We indicate with v_0 the value of procurement to the buyer when the investment is nil, clearly independent of n in this case. The investment fully depreciates at the end of the current period.

We do not model the pre-development phase, as this is typically not buyer-specific.

After the investment phase, a supplier is selected for production. We assume for the moment that production cannot be shared by more than one producer (in Subsection 4.3 we drop this assumption). Supplier i's cost of production is θ_{it}, assumed to be i.i.d. across firms 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 to the development phase, this necessitates an adjustment cost discussed below.

This procurement process is repeated for an infinite number of periods. The typical period is modeled as the following stage game.

t_1 *(Selection for development)*: The buyer *announces* to all N firms in the industry a desired minimal level of investment $\underline{I}$ and a number n $(\leq N)$ of firms, including their identity, that are invited to develop the blueprint of the intermediate product and to compete for its production.[25] The buyer *commits* to a transfer w to each one of the n firms to be paid at the end of the development phase t_2, and to a mechanism to be specified below, by which she selects the supplier obtaining the production contract at t_3 and determines her payment at t_4.

t_2 *(Development)*: Each invited firm i incurs sunk cost I_i towards his investment I_i.

[25] To simplify notation, we renumber the n firms selected 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.

This investment remains unobserved by the buyer until the end of t_4. The buyer pays transfer w to each of the n selected suppliers.

t_3 *(Selection for production)*: The buyer invites $\tilde{n}$ firms to compete for the production contract according to the mechanism she committed to in phase t_1. When she anticipates the possibility of selecting a non-developing supplier to produce with the blueprint developed by another firm, she needs to account for an ex-ante uncertain cost $k \geq 0$ private to and incurred by her, linked to the training of the non-developing supplier that needs to produce the part.[26] The number and identity of the $\tilde{n}$ firms selected by the buyer is public information. The production cost θ_{it} for each of these suppliers is realized. The buyer employs the mechanism she committed to, and selects a unique supplier h together with a price p payable on delivery of the intermediate product.

t_4 *(Production)*: The selected supplier h produces at cost θ_{ht} 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 is the assumption that suppliers do not compete directly on performance. Also for simplicity, we assume that the buyer's commitment to both the transfer w and to the mechanism used to allocate the production contract are contractible and, as such, enforceable by the courts. The mechanism the buyer commits to at t_3 differs depending on whether it involves competition or just one supplier. In the former case, it is a second price auction, and the price p for production is determined by that auction.[27] In the latter case, the buyer simply specifies the price p payable at t_3. Throughout the stage game we assume that the buyer has all the bargaining power, and both the buyer's and the suppliers' outside options are zero if the suppliers refuse the buyer's take-it-or-leave-it

[26] Confirming the importance of this cost of adaptation, in our data we find significantly fewer firms involved in the production stage the longer is the "lead-time" interval of development, that is the time between exact part specification by the buyer and the design freeze of finished blueprints (on average thirteen months). A longer lead-time makes non-developing suppliers even less familiar with the part to be produced. This also reflects the narrative on Lopez's stategy. It involved sending teams of engineers on site to the non-developing outsiders, for weeks, to train them to reliably produce the part on the basis of someone else's blueprint. When it became clear that the threat to bring in low cost/quality outsiders by training them to produce higher quality products with another firm's blueprint was 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.

[27] One could equivalently employ a first price auction, since we are assuming suppliers cannot collude. See Calzolari and Spagnolo (2009) for an explicit analysis of the interplay between relational procurement strategies and suppliers' collusion.

offer.

The level I_i invested by the typical supplier i, as well as the number $\tilde{n}$ of suppliers admitted to compete for production at t_3, are not contractible. Indeed, 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 will win the production contract.

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 agreed-upon levels of I and $\tilde{n}$. In particular, the typical supplier 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 for development.[28] Conversely, the buyer threatens to exclude from future procurements any supplier l observed at the end of t_4 to have deviated and invested at a level $I_l < \underline{I}$, and to replace him with another supplier from the $N - n$ suppliers not invited to the procurement process.[29]

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.[30]

We also assume that the buyer does not offer contingent payments such as discre-

[28]We address below the issue of whether the buyer prefers to bundle the investment contract (offered to n suppliers) with the production contract offered to $\tilde{n}$ suppliers, $\tilde{n} = n$. The answer clearly depends on the size of $E(k)$.

[29]Our assumptions on the punishment involved 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 (2008). Observe finally that within our model, the buyer's deviation is realistically observed in the entire industry, and therefore, the sellers collectively punish the buyer.

[30]The non-observability of the winning seller's investment before the end of the stage game is easy to justify within 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 (not very interesting) incentive compatibility constraint to prevent that a firm i sets $I_i = 0$, avoids winning the auction and systematically cashes in w (if positive). This constraint would have no effect on our results.

tionary bonuses.[31] The discount factor is one across all phases of the same stage game, and δ across different stage games. In line with the emerging literature on trust and relational contracts (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.

4.2 Relational procurement with R&D investment

We now characterize the main properties of a relational procurement equilibrium in our model. We consider symmetric stationary relational contracts where first, the n suppliers selected by the buyer each develop the required blueprint by undertaking investment $I \geq \underline{I}$; and second, the buyer abstains from inviting more than the announced n suppliers to compete for the production contract, so as to deprive the suppliers of their IPRs.

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 to the winning and thus producing supplier. Given our assumption that 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 $\theta^e_{(2)}(n)$ the expected costs 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 $p = \theta_{(2)}(n)$, where $\theta_{(2)}(n)$ is the realized cost of the second-most efficient supplier. If instead $n = 1$, then obviously $\beta(1) = 1$, the single supplier's expected rent is $\pi(1) = p - \theta^e(1)$ where $\theta^e(1) = E(\theta)$, and p is the price the buyer commits to at t_1.

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

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

[31] 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 is able to defer paying the 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.

If instead the supplier decides to deviate and invests less than required, then he knows that the buyer will observe the deviation at the end of the stage game and exclude him 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

$$w + \beta(n)\pi(n) \geq \frac{\underline{I}}{\delta} \tag{2}$$

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

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

be the price the buyer expects to pay for production when she sticks to her promise in t_1 and 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 is

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

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, the buyer would expect that no supplier would ever invest in the future, and thus set the transfer to $w = 0$. The buyer's expected discounted payoff from deviating would be

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

where the first term reflects the buyer's returns in the current period (accounting for the cost of adapting the technology if the producer ends up being a non-developer), and the second term her returns in the future stage games, with v_0 denoting the value to the buyer if investment is nil. The buyer prefers not to deviate by inviting more than the selected n firms to participate in the procurement contest for production, if the incentive constraint

$$\delta \left[v(\underline{I}, n) - nw - v_0 \right] + (1 - \delta) k \left(\frac{N - n}{N} \right) \geq p^e(n) - p^e(N) \tag{3}$$

is satisfied. That is, if the current expected savings in her payment for the production of the intermediate good from having all N rather than n firms compete, $p^e(n) - p^e(N)$, is not larger than the loss in the value of procurement (net of the transfers nw) she will face in the future. 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 relational contract that is incentive compatible for the buyer for any 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.[32]

The optimal procurement program $\mathcal{P}$ of the buyer is then

$$\begin{aligned} \max_{\underline{I}, w, n} \quad & \left[v(\underline{I}, n) - wn - p^e(n) \right] \tfrac{1}{1-\delta} \\ s.t. \quad & w + \beta(n)\pi(n) \geq \underline{I}/\delta \qquad (IC_s) \\ & \delta \left[v(\underline{I}, n) - wn - v_0 \right] \geq p^e(n) - p^e(N) \quad (IC_b) \end{aligned}$$

On the one hand, if the buyer wants to induce high investment, she has to account for the typical supplier's incentive not to deviate, here represented by (IC_s). This puts a limit on $\underline{I}$. Also, increasing the number n of competing suppliers reduces the cost of production, and with it, the expected price $p^e(n)$ the buyer has to pay. At the same time, increasing n adversely affects the typical supplier's incentive to provide the required investment, because the expected rent $\beta(n)\pi(n)$ decreases in n.

On the other hand, a larger n reduces the buyer's temptation to deviate, since the

[32]We will show that the buyer's incentive compatibility constraint (3) does not affect our ensuing analysis. Observe, however, that when the buyer invites just one supplier, so $n = 1$, the deviation to inviting more firms is dominated. The buyer would have to pay p to the (initially) single firm in any case, independently of subsequently organizing an auction with more firms: the r.h.s. of (3) would be $p\delta - p^e(N)$ and the constraint always satisfied. In passing, it is worth noticing that the contractibility of n would eliminate the buyer's incentive constraint (3).

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 with n. Summarizing, a higher discount factor δ helps to better control both, the buyer's and the suppliers' incentives to deviate.

It is immediately apparent that an optimal solution requires the buyer to always adjust the transfer w so that the incentive constraint (IC_s) is necessarily binding, otherwise the buyer could reduce w, thus both increasing the value of her objective function and relaxing her incentive constraint (IC_b). We can derive 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 *Ceteris paribus, a higher discount factor δ is associated with*
(i) a higher level of investment $\underline{I}$,
(ii) a larger number of suppliers n.

In particular, since (IC_s) is binding

$$w + \beta(n)\pi(n) = \frac{I}{\delta}, \tag{4}$$

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 higher investment—that is higher value for the final product.

The *overall* effects of a change of δ on the *actual* terms of procurement are more involved than the comparative statics of Proposition 1. Imagine, for example, that an increase of δ induces a higher level of investment $\underline{I}$, as in point (i) of Proposition 1. The overall effect of this increase in δ on the number of firms 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, the higher δ may actually call for a reduction in the number of firms n, because the buyer should grant larger informational rents to create incentives for the selected suppliers to invest even more. Analyzing the overall effects of δ on the optimal procurement instruments is therefore more complex because it requires us to account for all such indirect effects. In particular, we need to solve the buyer's procurement program $\mathcal{P}$ and verify the effect of δ on optimal procurement ($\underline{I}^*$,n^*). Rather than providing a full solution to program $\mathcal{P}$, we exploit some of its properties to verify under which conditions 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—persists.

Since w is implicitly defined by (4), we can rewrite the buyer's per-period objective function as a function of the two main decision variables $\underline{I}$ and n,

$$H(\underline{I}, n) = v(\underline{I}, n) - n\frac{\underline{I}}{\delta} - \theta^e_{(1)}(n) \tag{5}$$

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 $\theta^e_{(1)}(1) = \theta^e(1)$).

To determine the effect of the discount factor δ on the optimal number of firms n^* and level of investments $\underline{I}^*$ one can then rely on the maximizers of the buyer's per period payoff $H(\underline{I}, n)$. For a given n, denote $\underline{I}_n$ the maximizer of $H(\underline{I}, n)$ defined by

$$v'(\underline{I}_n, n) = \frac{n}{\delta}. \tag{6}$$

This condition shows that if δ increases and the optimal number of firms n^* remains unaffected, then the optimal level of investment increases. This observation immediately leads to the following conclusion.

Proposition 2 *An increase of the discount factor δ necessarily induces an increase of* at least *one of the two optimal procurement variables n^* and $\underline{I}^*$. Both n^* and $\underline{I}^*$ 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 below we illustrate this sufficient condition on the value of investment $v(\cdot,\cdot)$. Thus 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^* and $\underline{I}^*$.[33] This result contrasts with the intuition that trust requires

[33] The optimal transfer w^* is actually a residual variable determined by the binding constraint (4) , which shows that increases of both n^* and $\underline{I}^*$ 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^*.

an intimate relationship, that is altered by competition.

We have so far considered a relational contract where each of the n suppliers develops the required blueprint and the buyer invites to compete for the production contract these suppliers only. In this framework the buyer chooses n^* by optimally trading off gains from increased production efficiency with investment costs for the additional blueprints, much like in Che and Gale (2003).

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 k of adapting the blueprint developed by some supplier to the production line of someone else (the associated reduction of n with unbundling also directly hurts the buyer when $v_n > 0$). In the Theoretical Appendix we show that whenever the expected cost of adaptation $E(k)$ is large enough, unbundling development and production is dominated by the relational contract that we have considered. 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 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 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 this is never the case for complex systems.

The next section moves one step further and explicitly accounts for the possibility of having more suppliers active in production.

4.3 More than one supplier in series production

The management literature regards "supply assurance" as a crucial motive behind dual-sourcing, that is, simultaneously procuring an input from different suppliers. The buyer hedges against the possibility 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.[34] 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. We consider this trade off in our setting by assuming that an adverse event (is observable and) takes place with probability α, in which case the unique supplier would be able to procure just a fraction $1-\gamma$ of the required production.

Facing this risk of incomplete procurement—the costs of which we do not explicitly model, for simplicity—the buyer may plan to choose dual-sourcing and allocate two production contracts. The first-source contract exhausts the entire production with probability $1-\alpha$. With complementary probability α the first-source contract will provide the fraction $1-\gamma$ of production. The second-source contract, under which the complementary fraction γ is supplied, will be executed only if the adverse event occurs. Since the buyer will never allocate the two contracts to the same supplier, thus exposing herself to the risk of incomplete procurement, 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).

Consider now the two alternatives for the buyer: to procure with single-sourcing as in the previous section and face the risk of incomplete procurement, or with dual-sourcing using the multi-unit auction design described above. 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. Yet dual-sourcing 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 $\pi_2(n)$.[35] Since $\pi_1(n)\geq\pi(n)$, dual-sourcing guarantees a larger expected rent to

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

[35] To simplify notation we assume that a firm i that procures a fraction of total (unitary) production

suppliers. With an argument similar to that in the previous subsection, we obtain:

Proposition 3 *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.*

Although the thresholds for concavity of Proposition 3 and of Proposition 2 are not the same (see the Theoretical Appendix), the result is based on a similar mechanism. First, dual-sourcing guarantees a larger rent to suppliers than single-sourcing. Hence, as in the previous section, 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, this higher investment and larger number of suppliers implies that the actual cost of development with dual-sourcing $(n_d^* \underline{I}_d^*)/\delta$ is higher than the equivalent $(n^* \underline{I}^*)/\delta$ 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.

5 Adressing alternative explanations

In Section 3, we presented evidence on two aspects involving the buyer-supplier relationship. First, as one would expect from the predictions of the incomplete contract literature (Grossman and Hart, 1986; Hart and Moore, 1990), higher trust in a supply relationship is associated with significantly higher investment by suppliers proxied, as usual in the empirical literature on the topic, by lower failure rates of parts. Second, as one would not necessarily expect *a priori*, 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 those phases in which supplier investment is not relationship specific, such as pre-development.

faces a production cost which is the corresponding fraction of its cost θ_i. Then we have $\pi_1(n) = \theta^e_{(3)}(n) - \theta^e_{(1)}(n) \geq \pi_2(n) = \theta^e_{(3)}(n) - \theta^e_{(2)}(n) \geq 0$.

In Section 4, we developed a model that simultaneously explains these two relationships that together strike us as puzzling. The results of this model imply that higher established long term trust allows the buyer to request higher relationship specific investment from a given supplier, and simultaneously enables the buyer to induce more competition in development and production stages requiring relationship specific investment.

In this explanation, the level of trust is taken as exogenously given. This approach is based on the fact that our data are cross-sectional. While the assessment of trust is based on events and interactions covering decades, the central variables of interest—number of suppliers at the different development stages—only apply to the provision of a part for a specific car model, with negotiations for each part taking place at least annually.

In this section we consider potential alternative explanations of the empirical puzzle, discussed above. We proceed to address them on the basis of logical consistency and of evidence from our cross-sectional survey and from the case-study evidence on procurement behavior in the industry. Most importantly, we argue that higher competition cannot be the cause of the two effects we observe.

5.1 Does competition drive all results?

We start from a key competing hypothesis that could in principle explain all observed correlations and as such should be discussed first. Tougher competition could be the mechanism that leads to the unobserved selection of higher quality suppliers, or of suppliers that have exerted more effort, that then produce with lower failure rates. In this situation trust would be a result of lower failure rates rather than their cause. In other words, we would observe higher trust in both relationships only incidentally, but not as the actual driver of economic outcomes.

If this were the case, then we should expect to see significantly lower failure rates in relationships involving tougher competition. Moreover, this should be true potentially with regard to competition in all three stages of pre-development, development, and production. We can directly test this alternative hypothesis with the following fractional-probit specification

$$y_{ijs} = \beta * x_{ijs} + \gamma * Z_{ijs} + \kappa + \alpha_j + \epsilon_{ijs}, \quad (7)$$

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 with the controls used heretofore, κ is a constant, and α is a buyer-fixed effect.[36]

Notice that according to our theoretical model, trust would be an omitted variable in this specification, simultaneously having a positive effect on competition and on quality, which could lead to a positive correlation between the two showing up. Therefore we also use a specification including the trust index in Z. Our model would predict that correlation due to the omitted variable should be reduced when trust is included. We run the specifications for the number of suppliers in each of the development stages and report the results in Table 3 below.

Variables	**Pre-Dev.**		**Dev.**		**Ser. Prod.**	
number of suppliers	**.207****	**.219*****	-.063	-.024	-.065	-.028
	(.025)	(.009)	(.371)	(.736)	(.548)	(.795)
trust index	omitted	**-.272****	omitted	**-.184****	omitted	**-.185****
		(.032)		(.018)		(.024)
tech. Soph. (D)	-.512	**-.563***	.035	.019	.048	.034
	(.110)	(.058)	(.859)	(.918)	(.772)	(.840)
size of part (D)	**.909*****	**.817*****	**.730*****	**.682*****	**.539*****	**.500*****
	(.005)	(.004)	(.000)	(.000)	(.003)	(.004)
interaction	147	.174	-.143	-.069	.216	.256
	(.743)	(.691)	(.636)	(.832)	(.409)	(.353)
supplier revenues	.002	.005	-.005	-.005	-.009	-.009
	(.673)	(.369)	(.495)	(.436)	(.117)	(.114)
const	-1.522	-.223	-1.016	-.175	-1.070	-.206
	(.000)	(.727)	(.000)	(.678)	(.000)	(.000)
Buyer-FE (11)	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
# observations	74	74	126	126	127	127

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 3: Quality Issues and Competition: Fractional Probit-regression results

There is no significant negative effect of the number of competing suppliers on failure rates during any stage. 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. Indeed the opposite is the case. For the number of suppliers in the stages involving

[36]See Table 10 in the appendix for the results excluding buyer-fixed effects.

relationship specific investment, there is no significant effect, and for pre-development we even get the opposite of the expected sign.

For 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 predictions of our model. As importantly, the effect of trust on quality remains highly significant. This further indicates 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 could indicate 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, if our theoretical mechanism does explain the result as we claim, then we should expect from the model that more competition has a negative effect on suppliers' information rents. In the survey, we ask the suppliers for their assessment of the share of their development costs reimbursed by the buyer via a markup on produced parts, which is a, clearly imperfect, proxy for the information rent of the supplier. Controlling for type classifications and buyer fixed effects, we find that an additional supplier in development and series production is associated with reductions in the development-cost shares reimbursed via markups by 9.9 (development) or 21.1 percentage points (series production), respectively, compared to an average share of 54.7 percent.[37]

Therefore, competition appears unrelated to investment, 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 and make us confident in rejecting the alternative hypothesis that competition simultaneously drives all of our central results.[38]

[37]Notice that additional suppliers in series production includes an additional effect through lower production volume per producer.

[38]Notice that 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).

5.2 Reverse causality: Trust and Investment

We show above that there is no direct relationship between competition and failure rates, so competition cannot be the driver of the entire pattern that we observe. Yet it might explain part of it. Given the cross-sectional structure of our data set, determining the direction of causality between trust and investment is an issue. Less investment by the supplier might indeed lead to quality issues and therefore negatively affect the buyer's trust in the supplier. It is important to notice that in our data set, these quality issues are not related to legal conflict in the relationships; for 99.5% of part relationships that we observe, the respondents report relationship histories without any legal conflict (i.e, in all but one of the answers – and the one exception reports no quality issues having ever occurred). The absence of legal action is by itself indicative of the importance of the informal nature of the buyer-supplier relationship. We can thereby rule out that legal conflicts resulting from part failures are responsible of the destruction of the trust relationship.

To further explore this issue, we focus on a trust measure directed from the supplier to the buyer, which we only observe for a sub-sample of relationships. The supplier initiated the pre-development cooperation with a particular buyer and assessed the trust relationship with that buyer within that specific pre-development context. The supplier was asked how important his trust in the buyer was for his decision to initiate a pre-development cooperation with this buyer.

The response, for which we use the shorthand $trust_{PD}$, is measured on the same scale as the questions determining our preferred trust index. It is very sensitive to IPR conflicts between the parties, with a high negative conditional correlation of -0.64, which is what we would expect from a directed trust measure given the industry background. 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, more than 12 percent lower part failure rate for the slightly smaller sample; see Table 4 below. This indicates that higher directed supplier trust is associated with significantly lower failure rates. Therefore the underlying mechanism is not that higher failure rates let the trust of buyers in a given supplier deteriorate.

Most importantly, our primary argument against pure reverse causality is that 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. Our survey exercise was explic-

Variables	Fractional-Probit$^{\heartsuit}$	
trust$_{PD}$	**-.125****	**-.123****
	(0.015)	(0.022)
tech. Soph. (D)	-.003	-.010
	(.990)	(.964)
size of part (D)	**.709*****	**.751*****
	(.000)	(.000)
interaction	-.102	-.076
	(.802)	(.845)
supplier revenues	-.003	-.002
	(.690)	(.747)
const	-.748	-.603
	(0.003)	(0.037)
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) – 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 4: Directed (supplier) trust in pre-development, and investment proxied by quality issues: Fractional-probit results

itly organized by the industry body due to a "crisis of trust" in automotive procurement, resulting from confrontational procurement practices introduced in the early 1990s. To emphasize this point, we present some of the central determinants of our trust measure. For this, we turn to the suppliers' evaluation of confrontational procurement behavior by buyers in the past as identified in our questionnaire by the treatment of suppliers' IPRs and price renegotiations. We use the reported frequency of conflicts regarding the treatment of patents and trade-secrets as well as the frequency with which the buyer passes technological secrets of the supplier on to third parties without permission in the pre-development and development stages.

Additionally, for pre-development we look at the degree to which the OEM shares the (considerable) risk of higher than expected costs and for series production, we use an evaluation of the frequency with which the OEM demands lump-sum price reductions in renegotiations. For each of these trust determinants, we carry out OLS-regressions with the central trust-measure (trust index) as the dependent variable and the measures mentioned above as explanatory variables, while controlling for part characteristics and supplier revenues as above. For brevity of presentation, column (1) of Table 5 includes only the coefficients and p-values of these separate regressions.

	(1) trust index	(2) quality
Pre Development		
Frequency IPR conflicts	**-.469*** **	**.425*** **
	(0.000)	(0.002)
How often does OEM leak supplier's IPR	**-.268*** **	.127
	(.000)	(0.126)
OEM shares risk of higher development costs	**.136** **	.143
	(.034)	(0.138)
Development		
Frequency IPR conflicts	**-.230*** **	**.205** **
	(.001)	(0.016)
How often does OEM leak supplier's IPR	**-.130*** **	**.091* **
	(.018)	(0.063)
Series Production		
Frequency price renegotiation (lump sum)	**-.159*** **	**.021**
	(0.002)	(0.758)

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 only the coefficient and (p-value) of the trust determinant for each regression.* significant at 10%; ** significant at 5%; *** significant at 1%

Table 5: Determinants of our Trust Measure

The picture that emerges from these conditional correlations is very clear. Confrontational or opportunistic behavior by the buyer in the past is highly detrimental to our trust measure. The relatively small number of observations however raises standard issues associated with weak instruments, if we attempt to instrument trust with these determinants. As an alternative approach, we directly regress the likelihood of quality issues arising separately on each determinant and our typical controls in a reduced-form approach, using fractional probit regressions. If they are the driver of quality issues via reduced trust, then their effect on whether quality issues arise should have the opposite sign to trust. We report the coefficient of the determinants on the likelihood of quality issues arising in column (2) of Table 5. Except for risk sharing with regard to development costs (which does not have a significant effect on quality, though), this finding holds true for each regression. Conflicts associated with IPRs and leaks by the OEM—that were a staple of the confrontational procurement strategies in the 1990s—have a sizable significant effect with regard to whether quality issues arise. This pattern of behavior, in particular with regard to IPRs, was surely not determined by current quality issues.

5.3 Alternative explanations to trust and investment

A further worry could be that we might be omitting some characteristic of suppliers which both affects trust and quality positively. Recall that we introduce buyer-dummies in the basic specifications, because complementary buyer investments and overall procurement strategies are obvious issues to be addressed. On the supplier side, we believe that we address product-related differences through the type specification and size-related or bargaining power-related characteristics through supplier revenues in our basic specifications. But other supplier-specific factors may not be 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 an additional sets of fixed effects, supplier dummies (column 3) as well as, in addition, buyer dummies interacted with part dummies (column 4), into the investment regression from Section 3 above, yielding:

$$y_{ijs} = \beta * x_{ijs} + \gamma * Z_{ijs} + \kappa + \alpha_j + \mu_s + \alpha_j * type_i + \epsilon_{ijs}, \tag{8}$$

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, obviously omitting supplier revenues, κ is a constant, α_j 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. Including the latter implies that identification is only guaranteed using differences in quality and trust across suppliers for given parts and buyers in the final specification. We report the results of the fractional probit regression in Table 6 below. For ease of comparison we also include the columns (1 and 2) with the original regressions.

The central result, the coefficient of trust, remains almost unchanged. What we do observe is that the effects of part characteristics are mostly absorbed by the supplier dummies, indicating collinearity between our standard controls and the supplier fixed effects. The results are therefore robust to the inclusion of supplier dummies as well as interactions of these dummies with part type.

Further, part failure rates may be negatively related to the buyer's unobserved supplier-specific complementary investment, with investment increasing in supplier trustworthiness. In this interpretation, the supplier's part-specific investment could be com-

Variables	Fractional-Probit♡			
trust index	**-.155****	**-.191****	**-.208****	**-.207****
	(0.044)	(0.018)	(0.022)	(0.044)
tech. Soph. (D)	.055	.026	.034	.278
	(.770)	(.890)	(0.891)	(0.668)
size of part (D)	**.656*****	**.675*****	.243	.433
	(.000)	(.000)	(0.267)	(0.397)
interaction	-.116	-.055	.029	-.859
	(.728)	(.866)	(0.946)	(0.388)
supplier revenues	-.006	-.006	omitted	omitted
	(.457)	(.371)		
const	-.558	-.162	-.002	.059
	(0.131)	(0.703)	(0.997)	(0.923)
Buyer-FE (11)	**no**	**yes**	**yes**	**yes**
Supplier-FE (13)	**no**	**no**	**yes**	**yes**
Buyer-Part-FE	**no**	**no**	**no**	**yes**
# observations	126	126	126	126

The table reports regression results for the following dependent variable: ♡ frequency of quality problems arising (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: Trust and investment proxied by quality issues: Fractional-probit results

pletely unrelated to the part's failure rate and to the trust relationship. However, buyer fixed-effects should address this issue.

Higher trust could also lead to the self-selection of higher quality suppliers into the procurement relationship. Higher quality suppliers could produce with lower failure rates, at given investment level. Again, supplier selection is under the control of the buyer. However, an order overflow combined with capacity restrictions may lead a particularly competent supplier to withdraw from the contest. We consider capacity restrictions arising at a particular supplier as being random across buyers. At any rate, any deviation from this assumption should be taken care of by the supplier fixed-effects.

5.4 Alternative explanations to trust and competition

We finally consider alternative explanations to our argument that higher trust allows the buyer to implement more intensive competition in development and production. To begin, let buyers realistically differ by profitability, for instance, because of different success rates in model design. All else given, a more profitable buyer should be more trustworthy to the typical supplier. In addition, a more efficient/profitable buyer could also benefit more from finding a better supplier if there are complementarities in production. To find a better supplier that also produces with lower failure rates, the more profitable buyer could increase the number of suppliers competing in procurement. Alternatively, more suppliers could be willing to deal with a more trustworthy buyer. All these arguments would lead to the observed correlations between trust and competition, and trust and failure rates, respectively.

However, these alternative arguments are captured by the buyer fixed-effect in our estimates. The buyer fixed-effect controls for differences in buyer profitability and complementarities in production. Summarizing, we currently cannot conceive of an alternative to the causation derived from our theoretical model, that increasing mutual trust allows the buyer to invite more suppliers into competitive procurement.

6 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.

Largely due to lack of other data, 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 as fostered or squandered in specific pairwise economic relationships related to the exchange of particular commodities and services. We do this by means of a theoretical analysis and a corresponding empirical investigation involving first-tier buyer-supplier relationships in the German automotive industry.

We first demonstrate empirically—to our knowledge for the first time—a theoretically well known fact that higher levels of trust are associated with higher relationship-specific investment. More surprisingly, we show that higher levels of trust are associated with more intensive competition amongst suppliers as induced by the buyer.

We then develop our preferred explanation of these associations within a relational contracting model involving one buyer and several suppliers. It involves components of buyer and supplier behavior that are unobservable at the relevant decision stage, and thus enforceable only via a higher continuation value in an infinitely repeated game in which opportunistic short term rent-seeking is dominated by the value associated with long-term cooperation. Within this model, we show that 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 product development and production within her procurement scheme for typical parts.

We then detail a number of competing explanations, including reverse causality, and show with one exception that they are either taken care of in our empirical analysis, or can be excluded on the basis of our empirical evidence. We give only plausible support, but cannot exclude reverse causality for our interpretation involving trust and investment, namely that increasing trust causes higher supplier investment, resulting in decreasing numbers of part failure rates.

This has no implication on our main result that higher trust results in more intense competition amongst suppliers in relationship-specific development and production. It implies that trust and the quasi-rents from limited competition behave like substitutes in terms of sustaining cooperative behavior—higher non-contractable investment—between the buyer and the sellers.

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Empirical Appendix

Data Base

All 10 German automotive producers—7 producers of passenger cars and 3 truck makers, and a selected set of 13 German parts suppliers participated in the study. All participating suppliers had representatives on the VDA's board. This ensured that the respondents—high-ranking employees selected by the boards of the participating firms—were willing to exert the required effort when completing the questionnaires.

The supplier sample is biased 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. One might worry that large suppliers are able to exert monopoly power over the downstream producers for some of the parts we study, leading us pick up the effects of differentials in relative bargaining power vis-a-vis buyers instead of differentials in trust. Using data from a separate commercial database,"Who supplies whom 2007" collected by supplierbusiness.com, we verified that each product in our sample was produced by at least two firms active in the German market. These suppliers had interacted with the buyers over many years and in the development and production of many parts. This, together with Lopez' intervention makes the interaction between them an ideal subject for the analysis of relational contracts.

The questionnaire was developed by three scientists, and reviewed in detail by a team of 15 senior management representatives of both buyers and suppliers before going online.[39] In particular, the representatives were in charge of developing the key definitions and the measurement scales used in the questionnaire. Substantial effort was dedicated to making sure that it was possible to control for the relevant differences in product characteristics.[40] For this, products had to be representative of one of four product classes:

Commodities: physically small and technologically unsophisticated (e.g. shock absorbers);

[39]The scientists in charge were Prof. Wilhelm Rall, a senior specialist at McKinsey&Co for the automotive industry, Konrad Stahl and Frank Wachtler.

[40]Part prices are extremely sensitive information and were therefore not contemplated in the survey.

(High-tech) Components: physically small but technologically sophisticated (e.g. electronic sensor clusters);

Modules: physically large but technologically unsophisticated (e.g. complete front ends, sometimes assembled by the supplier);

Systems: physically large and technologically sophisticated (e.g. electronic systems).

These product classes allow us to distinguish both according to the technological sophistication of products as well as according to their physical size.

Each participating supplier was asked to evaluate his relationship to 11 buyers in clinical detail (the 10 German automotive producers plus a foreign firm included as a reference player), conditional on the fact that at least one product from one of the four product groups was supplied to the buyer in question at the time of the survey. The questionnaires were filled in by the responding supplier's representatives in charge of development, production, or sales of the product, respectively; engineers; procurement, and sales officers.[41] In most cases, different individuals contributed answers to those subsets of questions relevant to them for each part and buyer. To obtain a complete observation, we merged the answers from a supplier firm for a given buyer and part across the different functions. Whenever parts of questionnaires overlap, we use the arithmetic mean of the responses. An observation in our empirical approach represents a given supplier's view—that is the aggregate view of the employees that were asked to fill the questionnaire—of the relationship with a given buyer for a specific product representative of one of the product classes.

With regard to survey participation, at the supplier/buyer/product group level, there are 13 (suppliers) x 11 (buyers) x 4 (product groups) = 572 potential relationships. In fact, out of the 13 suppliers, only 6 sell products from each product group, with 3 firms limited to 3 types of products, 4 firms limited to 2 types of product, and 1 firm only selling 1 type of product. Since, additionally, not every supplier provides 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 remaining

[41]A participant was first asked to indicate his function within the company out of the following seven functions: *pre-development*, *vehicle development*, *series production*, *quality control*, *sales*, *logistics*, and *aftermarket production*. For each product and customer, he would then answer the set of questions suited to his function within the company. For a detailed description of the individual functions and the automobile development and production process, we refer to Müller, Stahl, and Wachtler (2008).

variation in the number of observations is due to the facts that a) not each supplier's representatives answered all sets of questions, which leaves our merge incomplete; and b) individual questions could be skipped.

The fact that individual questions could be skipped has implications on the choice of our sample. 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 the observation to include answers to these three questions. Therefore there is no sample-composition issue across the relevant regressions. 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.

We concentrate on three distinct phases of the life-cycle of any part: buyer/model-unspecific *pre-development*, buyer/model-specific *development*, and *series production* of that part. In *series production*, suppliers work with a blueprint for the part and model-specific tools. Only then can the product and services exchanged be relatively clearly formalized in details. This is not yet possible in the model-specific, and therefore buyer-specific *development* phase. While the desired functionality of the part is described in the buyer's performance requirements, complex interfaces with other parts (often under development at the same time) cannot be specified *ex ante*. The intended outcome is blueprints for the part. *Pre-development* covers basic R&D on new technology, often purely based on the supplier's initiative. By necessity, even if this involves contracts, they cannot be clearly specified.[42]

One questionnaire contains 185 questions and 150 sub-questions extending over all phases, including retrospective questions related to a given part. In spite of our data being purely cross-sectional, this allows us to use responses on the pre-development and the development of the currently supplied part to integrate longitudinal aspects into our analysis.

Finally, a potential issue with our trust measure is that respondents could have idiosyncratic interpretations of what is *important* with respect to the given scale, which may result in measurement error. The question of the importance of trust was posed in a specific context; suppliers were also asked to evaluate the importance of price on

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

supplier selection. To address the potential measurement error, we also normalised our first measure by taking the difference between the importance of trust and of price (that is, the importance of trust relative to the importance of price) and used this as an alternative. All results remain qualitatively unchanged, see tables 11 and 12. In the following, this alternative measure is referred to as **trust index (n)**. Notice the larger standard deviation when interpreting the results.

Descriptive statistics

Table 7 exhibits the basics on the trust indices employed in our analysis,

Variable	Mean (Std. Dev.)	Min	Max	Obs.
Trust index	4.83 (.79)	1.5	6	296
Trust index (n)	- .63 (1.06)	-4	2.67	295

Table 7: Trust Index Summary Statistics

Table 8 contains the central variables—net of our trust measures—used in our regressions and robustness checks, and in the discussion of bivariate relationships.

Variable	Mean (SD)	Min	Max	Obs.
Probability of quality issues arising due to part	.16 (.21)	0	1	197
Number of competing suppliers during pre-development	2.18 (.83)	1	5	144
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
Lump sum compensation for development (share of costs)	.28 (.27)	.1	.9	183
Frequency of supplier IPR being leaked by buyer	.324 (.243)	0	1	245

Table 8: Dependent and independent variables summary statistics

Our central controls are related to the technological sophistication and size of the part; as set out above, this information is embedded in the design of the survey through the type of product for which the answers were provided by respondents. 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. We introduce dummies for the technological sophistication (this takes a value of 1 for systems and components) and for size of part (this takes a value of 1 for systems and modules). For a subset of our data, we observe the R&D cost share of parts. It is in fact 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. The interaction between the two captures effects that are specific to systems, which combine technological complexity and larger size. In a robustness check, we introduce the R&D cost share instead of the technological sophistication dummy and the interaction, see columns 3 and 4 of table 11, below. Overall results are unchanged, but for a considerably smaller sample. Finally, we introduce the 2007 revenues of the supplier in question as a proxy for supplier bargaining power.

Table 9 displays pairwise correlations between the main variables of interest. We see that trust tends to be slightly 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. Quality problems are negatively associated with trust and occur more frequently for larger and more complex parts. Notice that there is no significant correlation between trust measures and the type of part under consideration or the supplier revenues. Passing on suppliers' IPR during the pre-development phase is significantly negatively correlated with both trust measures.

	trust ind.	**trust ind. (n)**	**fail. pr.**	**ls. comp.**	**# sup. PD**	**# sup. dev**	**# sup. SP**
trust index (n)	**0.8203*** **						
(p-level, obs)	(.000, 295)						
failure prob.	**-.1878** **	**-.1532***					
(p-level, obs)	(.019, 155)	(.057, 155)					
ls. comp. share	.0131	.0288	.0782				
(p-level, obs)	(.860, 183)	(.699, 183)	(.426, 106)				
# suppliers PD	-.1094	**-.1559***	-.1108	.0260			
(p-level, obs)	(.227, 124)	(.084, 124)	(.334, 78)	(.818, 81)			
# suppliers dev	**.1189***	.0385	-.0684	**-.1890** **	**.4343*** **		
(p-level, obs)	(.010, 193)	(.595, 193)	(.447, 126)	(.041, 117)	(.000, 111)		
# suppliers SP	.0419	.0749	-.1246	**-.1382***	**.4116*** **	**.5194*** **	
(p-level, obs)	(.540, 216)	(.273, 216)	(.163, 127)	(.065, 179)	(.000, 86)	(.000, 136)	
supplier rev.[a]	.0832	.0127	-.0767	**-.1479** **	.1217	**.1598** **	.0129
(p-level, obs)	(.153, 296)	(.828, 295)	(.284, 197)	(.046, 183)	(.178, 124)	(.026, 194)	(.850, 216)

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

Variables	**Pre-Dev.**		**Dev.**		**Ser. Prod.**	
number of suppliers	**.157***	**.151*****	-.049	-.022	-.068	-.010
	(.084)	(.088)	(.472)	(.736)	(.507)	(.898)
trust index	omitted	-.093	omitted	**-.149****	omitted	**-.180****
	(.388)		(.046)		(.018)	
tech. Soph. (D)	-.446	-.453	.057	.048	.065	.052
	(.145)	(.129)	(.768)	(.801)	(.682)	(.738)
size of part (D)	**.909*****	**.885*****	**.691*****	**.660*****	**.512*****	**.486*****
	(.001)	(.002)	(.000)	(.000)	(.004)	(.005)
interaction	-.092	-.081	-.181	-.127	.155	.230
	(.836)	(.856)	(.560)	(.697)	(.576)	(0.429)
supplier revenues	.006	.007	-.004	-.005	-.008	-.009
	(.245)	(.199)	(.560)	(.504)	(.167)	(.145)
const	-1.692	-1.223	-1.235	-.554	-1.140	-.321
	(.000)	(.037)	(.000)	(.137)	(.000)	(.396)
Buyer-FE	**no**	**no**	**no**	**no**	**no**	**no**
# observations	74	74	126	126	127	127

The table reports regression results for the following dependent variables: Frequency of quality issues arising for that 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 10: Quality Issues and Competition: Fractional Probit-regression results

Variables	**Fractional-Probit**♡					
trust index (n)	**-.109***	**-.123***	**-.142***	**-.148****	**-.156****	**-.218****
	(0.061)	(0.057)	(0.073)	(0.023)	(0.037)	(0.028)
tech. Soph. (D)	.068	.108	.326	omitted	omitted	omitted
	(.723)	(.659)	(.627)			
cost share R&D	omitted	omitted	omitted	**.031***	.024	.006
				(0.051)	(0.164)	(0.718)
size of part (D)	**.673*****	.242	.450	**.749*****	**.366***	.059
	(.000)	(.283)	(.364)	(0.000)	(0.065)	(0.703)
interaction	-.069	.038	-.723	omitted	omitted	omitted
	(.829)	(.927)	(.470)			
supplier revenues	-.007	omitted	omitted	-.003	omitted	omitted
	(.334)			(0.540)		
const	-1.142	-1.142	-1.061	-1.280	-1.280	-1.271
	(0.000)	(0.018)	(0.002)	(0.000)	(0.000)	(0.003)
Buyer-FE (11)	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
Supplier-FE (13)	**no**	**yes**	**yes**	**no**	**yes**	**yes**
Buyer-Part-FE	**no**	**no**	**yes**	**no**	**no**	**yes**
# observations	126	126	126	97	97	97

The table reports regression results for the following dependent variable: ♡ frequency of quality problems arising (in percent) – coefficients and (p-values) reported. Columns 3 and 4 include the share of R&D in part costs as an alternative measure for the technological sophistication of a part; standard errors are clustered at the level of buyer-seller pairs; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 11: Trust (using the normalized trust measure) and investment proxied by quality issues: Fractional-probit results

Variables	**Pre-Dev.** ♠		**Dev.**♣		**Ser. Prod.**♡	
trust index (n)	-.044	-.032	**.068****	**.112****	**.116*****	**.129*****
	(.186)	(.430)	(.035)	(.035)	(.007)	(.006)
tech. Soph. (D)	-.102	-.098	**-.267****	**-.264****	**-.310*****	**-.328*****
	(.310)	(.317)	(.013)	(.016)	(.000)	(.000)
size of part (D)	**-.197***	-.121	.167	.213	**-.298*****	**-.268*****
	(.073)	(.292)	(.297)	(.128)	(.000)	(.000)
interaction	.194	.104	-.444	**-.494***	.169	.110
	(.285)	(.580)	(.171)	(.069)	(.312)	(.467)
supplier revenues	.002	.004	**.024*****	**.027*****	.005	**.007***
	(.561)	(.216)	(.000)	(.000)	(.225)	(.093)
const	.795	.543	.291	.072	.391	.212
	(.000)	(.000)	(.003)	(.615)	(.000)	(.001)
Buyer-FE (11)	**no**	**yes**	**no**	**yes**	**no**	**yes**
# observations	78	78	126	126	127	127

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; standard errors are clustered at the level of buyer-seller pairs; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 12: Trust (using the normalized trust measure) and Competition: Poisson-regression results

Theoretical Appendix

Proof of Proposition 1.

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

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

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

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

together with

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

and

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

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

$$w = \frac{\underline{I}}{\delta} - \pi(1) \tag{9}$$

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

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

and

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

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.

Proof of Proposition 2.

Notice first that equation 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 (6). 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 (6) 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 (6) 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 (6) is smaller when n^* increases than when it remains constant.

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 of 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 cost of adaptation 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 adaptation $E(k)$ 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 (i.e. lower n') avoid the duplication of investment costs (the second term in the parenthesis). On the other hand, this increases the probability of facing adaptation 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 adaptation 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,

$$E(k)(1 - n'\beta(N)) + \left[\theta^e_{(1)}(n) - \theta^e_{(1)}(N)\right] \geq \left[v(\underline{I}, n) - \frac{n\underline{I}}{\delta}\right] - \left[v(\underline{I'}, n') - \frac{n'\underline{I'}}{\delta}\right]. \quad (10)$$

The left hand side indicates the production-adaptation cost of unbundling. The two

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

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 (10) implies the buyer prefers to bundle development and the possibility to produce.

Proof of Proposition 3.

From the binding suppliers' incentive compatibility constraint, as in (2), 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 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:

$$H_d(\underline{I}_d^*, n_d^*) = H(\underline{I}^*, n^*) \tag{11}$$

we have

$$n_d^* \underline{I}_d^* > n^* \underline{I}^* \tag{12}$$

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:

$$\frac{\partial H_d}{\partial \delta} = \frac{(n_d^* \underline{I}_d^*)}{\delta^2}, \qquad \frac{\partial H}{\partial \delta} = \frac{(n^* \underline{I}^*)}{\delta^2} \tag{13}$$

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.