Trust, Competition and Innovation:

Theory and Evidence from German Car Manufacturers*

Giacomo Calzolari
(Univ. of Bologna, CEPR)

Leonardo Felli
(LSE, CEPR)

Johannes Koenen
(Ifo Munich)

Giancarlo Spagnolo
(SITE, Tor Vergata, EIEF, CEPR)

Konrad O. Stahl
(University of Mannheim, CEPR)

February 2016

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 R&D investments, 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. We show in both theory and the data that trust and rents from reduced supplier competition are substitutes, rather than complements as typically assumed.

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 Columbia, Hebrew, Northwestern, Tel Aviv and Tsinghua Universities, Bologna, IIOC Chicago, Berlin, Copenhagen, ESSET (Gerzensee), Frankfurt (CEPR Workshop on Incentives and Organizations), Mannheim, Tor Vergata (Rome), and Warwick. We also benefitted from discussions with James Best, Maria Bigoni, Patrick Bolton, Jeff Butler, Chaim Fershtman, Maria Guadalupe, Pierre-Olivier Gourinchas, , Bentley McLeod, Hodaka Morita, Rob Porter, Wilhelm Rall, Klaus Schmidt, André Stenzel, Peter Vida and Luigi Zingales, and from detailed comments by Bob Gibbons and Giorgio Zanarone. Financial support from the Deutsche Forschungsgemeinschaft (SFB-TR-15) is gratefully acknowledged.

1 Introduction

Trust is a key ingredient of our social lives, and of business transactions alike. It particularly facilitates the implementation of informal relational contracts that can yield a higher surplus than legally enforceable ones. If a party trusts that she will be treated fairly by her trading partner, she will be more willing to invest in the relationship, and thereby increase the surplus and efficiency.

Business relationships often involve repeated sequences of exchanges. In such cases, trust-based relational contracts are considered to be efficient governance instruments for non-contractible dimensions. Such contracts typically involve dyads of firms consisting of one supplier and one buyer.

An interesting example of a trust-based relationship is the procurement of parts for complex products, such as automobiles. 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.

These long-term trust-based relationships in Germany are particularly interesting because of the changes in the supply chain introduced by Ignacio Lopez who 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 redistribute rents from upstream and restore VW's profitability.[1] Driven by the same quest for higher short run profitability, some other, but not the most profitable automotive producers followed suit and adopted aggressive procurement strategies, which caused considerable turbulence in industry relations. The long shadow of this turbulence prompted our high-level survey focusing on the trust relationship between first-tier suppliers and their buyers, the automotive producers, in the German automotive industry. Our evidence thus reflects a rather unique historical episode involving intra-industry variations in the buyer-supplier trust relationships.

[1] This essentially consisted in expropriating the supplier's intellectual property rights embodied in a blueprint, by using it without compensation to procure worldwide for production. The details of Lopez's professional career are summarised well *here*. For a discussion of its long shadow over Opel, a German daughter company of GM, see *here*. An English language collection of articles is found *here*.

Our first empirical finding is that higher trust levels in a relationship 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 to 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-based 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 long-term relationships 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 for the first finding, the second finding in our view represents 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 trust 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, and defend our preferred explanation against these.[2]

A buyer repeatedly procures a product. This involves the development of a blueprint requiring buyer-specific and non-contractible R&D investment by competing suppliers, followed by the production phase. There are several firms capable of developing such a blueprint and producing the part. The potential suppliers differ in production 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, invites one or more of them to invest in R&D and develop a blueprint for the part in question, and selects a winning blueprint at its end. One or more suppliers are then allocated the production contract, possibly through a competitive auction.

We focus on relational contracts featuring contractible and non-contractible components. On the buyer side the promise to select producers from the set of suppliers invited to the development contest is non-contractible. On the supplier side it is the R&D investment towards the blueprint that is non-contractible. A deviation by the buyer consists of

[2]We call this procedure a Neo-Popperian approach to establishing causal structure. It holds until a better one is provided.

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 insufficiently investing in development, that is, in the preparation of a blueprint as desired by the buyer. Upon observing this, the buyer can punish the deviator by excluding him from future procurement. Conversely, suppliers can punish a deviating buyer by reducing R&D investment for future blueprints.

In equilibrium the buyer maximises her expected profits, honoring the incentive constraints on both sides of the market that induce future cooperation. The buyer restricts herself to selecting a strict subset of suppliers from the total set for development and production. The rents generated in the production phase compensate for the non-contractible investment. We identify a sufficient condition under which a slack in this incentive constraint induced by an increase in trust allows the buyer to increase the investment desired from the typical supplier, as well as the number of suppliers invited to the procurement contest. In this situation, the associated decrease in future rents (due to increased competition) is compensated for by the larger value of future interactions (due to increasing trust). Hence *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 the 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 open to suppliers that had not undertaken relationship-specific investments.

The model and the results derived 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 reflect what can be interpreted as a new relational contracting equilibrium that, as a long-term consequence of the Lopez affair, resulted in significant variation in the levels of trust across individual supplier-buyer relationships.

Within the limitations of a cross-sectional survey with a relatively small number of observations, we carry out various robustness checks for the central results, to address potential measurement and endogeneity issues. We are able to make use of the fact that our survey extends over all phases of buyer-supplier interaction for a given part, pre-development, development and production. This allows us to instrument trust in different ways. Our favored instrument is the occurrence of opportunistic buyer behavior with regard to supplier IPR in the past. The results of our IV- and simultaneous equation models are stable and consistent with the predictions of our theoretical model.

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 following section, we present the empirical puzzle. In Section 3 we develop our theoretical model, and in Section 4 we detail our empirical analysis. We postpone the literature review to Section 5 because it helps clarify how our results relate to several theoretical, experimental and empirical literatures. We conclude with 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 the Theoretical Appendices, respectively.

2 The puzzle

Our questionnaire survey was conducted under the auspices of the German Association of Automotive Manufacturers (VDA) between the Fall of 2007 and the Summer of 2008 on the relationship between the automotive manufacturers in the German automotive industry—henceforth called "buyers"—and their first-tier suppliers.[4] In the aftermath of the aforementioned confrontational procurement practices enforced by some automotive producers, the industry was concerned that a crisis of trust was affecting the supplier-buyer relationship. Accordingly, the main motivations for the study were to

[3]See **?** for other interesting examples of procurement relationships involving the combination of unverifiable innovation and verifiable production components.

[4]The pilot case studies performed between November 2005 and May 2006 involved numerous interviews with high ranking representatives of first-tier suppliers' R&D, production and marketing departments, and automotive producers' procurement departments. **?** summarise the results of these case studies. They present a very detailed view of the relationship between producers and their first-tier suppliers.

determine the status quo in the industry and to develop ideas of how the long shadow of confrontation and mistrust could be amended. The survey is described in detail in the Empirical Appendix. Here, we concentrate on our measure of trust, and on the basis of this highlight the puzzling empirical relationship between trust and competition that emerges from a first regression.

2.1 A measure of trust

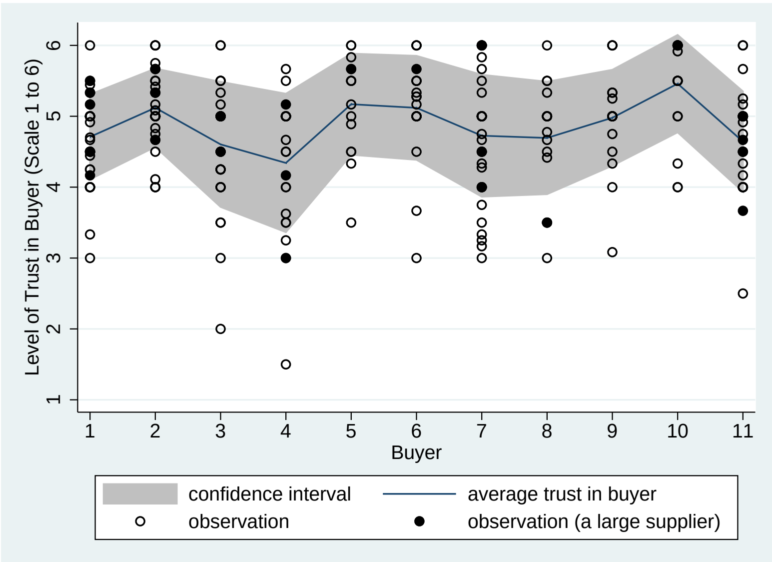
Trust is a sensitive concept which has proven to be somewhat elusive to attempts at explanation and measurement. The structure of our questionnaire provides us with a specification of trust that is relationship-specific, since it is associated with the bilateral interaction between two firms. More than this, the responding suppliers provided assessments of the trust relationship with a given buyer for individual parts and three development phases separately. These phases are pre-development, development and series production. Since the interactions across all three phases constitute the relationship with regard to a specific part, our measure averages the responses for the individual phases. Moreover the interactions between firms and especially the procurement strategies may depend on the part in question, therefore conditioning the analysis on the object of exchange strikes us as of the utmost importance.

In the survey, individuals responsible for the pre-development, development, and series production at supplier A were asked their evaluation of the trust relationship with company B regarding a specific part, as follows: "*Please evaluate the importance of mutual trust between the supplier and OEM for the OEM's supplier selection.*", where OEM (original equipment manufacturer) refers to the buyer. 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. This question was central to the entire survey, and thus was developed within an especially intensive discussion in the steering committee responsible for developing the survey questions. In particular, to avoid personalised responses questions were formulated in terms of *importance of trust* rather than *trust* directly.[5]

[5] The questionnaire survey contains other measures related to trust. Two questions are particularly close, but on a more specific topic: *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 others' intellectual property rights?* In a separate online appendix, available at *Trust Appendix*, we show that the responses are strongly positively correlated with each other.

The typical trust relationship reported in our survey involves the interaction between an automotive manufacturer and a long-term supplier. As procurement varies across types of parts, it is differentiated by these. The interviewed subjects are managers answering within their professional capacity. The manager's report on the importance of the trust relationship with a buyer is therefore likely to be driven more by the economic traits of the buyer of a particular part, such as her past behaviour and her management style, than by the psychological or sociological forces dominant in interpersonal relationships.

Our central measure of trust is the arithmetic mean of the suppliers' responses across the three development and production stages for 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 on the side of the suppliers. The resulting variable is referred to below as the "trust index".



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.

Furthermore, we report on how our trust measure is affected by other specifications of buyer behaviour, such as aggressive price re-negotiations. Finally, we report on a factor analysis demonstrating that significant shares of the variation in the responses to all trust-related questions can be explained by a single underlying factor.

We report the suppliers' responses to our key question in Figure 1. It displays the variation in trust in our data. On the one hand, suppliers' trust overall differs substantially across buyers. This likely 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. Finally, the solid gray dots represent the responses by a large supplier in the survey. They show that the level of trust with respect to the same buyer can differ, reflecting different procurement strategies across types of parts.

2.2 Trust, investment and competition: a puzzle

Our main focus is on the development stage, during which each supplier undertakes substantial development investment that is specific to the buyer's 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.

On average, only a minor share (30.4%) of the development expenditures is reimbursed directly by the buyer. Furthermore, the supplier's intellectual property rights (IPR hereafter), 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 IPR to competitors without their consent. This type of behavior is an example of how past interactions with regard to specific parts and the IPR 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). In fact, we use the incidence of this behavior as an instrument for trust in the IV-approach conducted in Section 5.

Against this background one would expect a positive association between buyer-supplier trust and the supplier's relationship-specific investment during development and series production. Such investment is unfortunately unobservable to us—and indeed, can hardly be isolated at the level of the individual part even by the typical supplier—but the literature suggests the (inversely related) failure rate of parts as its viable proxy.[6]

The regression in Table 3, discussed at length in Section 4 below, shows that, con-

[6]In our interpretation the investment and associated trust could be in terms non-contractible skills that a supplier needs to acquire to procure a specific part.

trolling for the type of part as well as the buyer (among other things), an increase in the trust measure related to a given part is associated with a significant and substantive decrease in the likelihood that this part suffers substantial quality problems.

The puzzle arises when we combine this evidence with our observations on competition as induced by the buyer in both the development and production stages. Recall that in the development stage, suppliers compete to produce the best blueprint, and to be selected for production on its basis. We observe that the more competition that is induced among suppliers is in the development stage, the more suppliers are actually employed in series production.[7] Moreover, the more competition in development, the lower the share of development costs that are directly (via a lump sum payment) or indirectly (via markups on produced parts) reimbursed by the buyer.[8] By inducing tougher competition, the buyer apparently exerts stronger pressure on the suppliers. Thus, we would expect suppliers to hate being subjected to tougher competition, with trust being among the casualties.

To our surprise, the opposite is the case. We find consistent and robust evidence that higher levels of trust in the relationship are associated with tougher competition induced by the buyer at both the development and series production stages, that is those stages in which relationship-specific investment is most relevant. The two regressions in Table 1, based on reports of the dyadic trust relationship differentiated by type of part supplied, show the relationship between trust and the number of suppliers employed in the 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 the buyer's identity.[9]

The two regressions need to be interpreted differently. In the development regression, the dependent variable involves the number of suppliers that competitively exert development effort. The buyer then chooses from them the winning blueprint for the part—and with it, the supplier who produces at least a substantive share, if not all, of that part. In the production regressions, the dependent variable is instead the number of

[7]The correlation between the number of suppliers at production and those competing at development stages is .54, p-value 0.000 (see Table 6 in the Appendix).

[8]The number of suppliers at each stage is significantly negatively correlated with the reimbursement shares, with both (direct and indirect shares) declining by around 10 % when adding an additional competitor.

[9]As Table 4 in Section 4 shows, this correlation is *not* observed for pre-development, that is the stage without relationship-specific investment.

Variables	**Devt. Stage**♣	**Prod. Stage**♡
trust index	**.318*****	**.167****
	(.009)	(.056)
technological sophisticated part (D)	**-.308***	**-.405*****
	(.065)	(.001)
large part (D)	.353	**-.380*****
	(.208)	(.001)
large and sophisticated part (interaction)	**-.711***	.249
	(.098)	(.148)
supplier revenues	**.004*****	.007
	(.001)	(.200)
const	-.587	.404
	(.387)	(.334)
Buyer-FE (11)	**yes**	**yes**
# observations	126	127
R^2	.266	.226

The table reports regression results for the following dependent variables: ♣ number of competing suppliers during the final stage of development – coefficients and (p-values) reported – ♡ number of competing suppliers at the start of series production – coefficients and (p-values) reported; the dummies for technological sophistication and size are according to the industry classification of parts into commodities (small, unsophisticated), compontents (small, sophisticated), modules (large, unsophisticated) and systems (large, sophisticated) discussed in detail in Section 4 * significant at 10%; ** significant at 5%; *** significant at 1%

Table 1: Trust and Competition: OLS-regression results

suppliers that produce the part in parallel. We will return to this distinction in Section 4, where a more detailed empirical analysis is performed.

In the development phase, an increase of trust by one standard deviation is related to an expected additional 0.40 suppliers, corresponding to an increase of more than 25%, compared to the average of 1.54 suppliers involved in this stage. In the series production phase, the coefficients are smaller. Still, an increase of the trust measure by one standard deviation is associated with 0.20 additional suppliers, relative to an average of 1.22 suppliers involved in that phase.

In sum, as one expects from the received theory, more trust is associated with higher relationship-specific investments by suppliers. Unexpectedly, however, more trust is also associated with tougher competition among suppliers at the development stage and more frequent co-sourcing at the production stage, while tougher competition also has a substantial negative effect on suppliers' reimbursement shares. In the following, we provide a theoretical model of relationship-specific investment, competition and trust in a dynamic procurement setting which incorporates each of these observations in combination. Then, we revisit our empirical findings in the light of the model's results and provide a number of robustness checks.

3 A model of innovative products

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, as long as the suppliers' R&D is an essential input into the final product.

3.1 Model elements

In each period a buyer (referred to as "she" for distinction) needs to procure an innovative intermediate product. This process entails first the development of a buyer-specific blueprint for such a product, which requires an R&D investment $I > 0$ in the development of that blueprint 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. The value of the final product with embedded investment I to the buyer is $v(I)$, which is an increasing and strictly concave function, $v'(\cdot) > 0$, $v''(\cdot) < 0$, and satisfies standard Inada conditions.

There are $N > 1$ firms capable of investing and supplying the intermediate product. In case the buyer selects more than one supplier for its development, the suppliers invest independently and competitively. There are no externalities and we do not model the pre-development phase, as it 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 3.3 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.

As investment I is buyer-specific, it has no value for buyers other than the one commissioning the intermediate product. The investment fully depreciates at the end of the current period. 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.

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

t_1 *(Pre-selection)*: 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.[10] 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 selected supplier i incurs sunk cost I_i towards his investment I_i. This investment remains unobserved by the buyer until the end of t_4. The buyer pays transfer w to each of the n selected suppliers.

t_3 *(Selection)*: The buyer invites $\tilde{n}$ firms to compete, on the basis of the blueprint provided by one of the n developing suppliers, for the production contract according to the mechanism she committed to in phase t_1.[11] 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 k together with a price p payable on delivery of the intermediate product.

t_4 *(Production)*: The selected supplier k produces at cost θ_{kt} 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.[12]

[10] For simplicity, we renumber the n firms selected so that these are the first n ones. $\underline{I}$ reflects performance specifications in a functional procurement process. Performance specifications are outcome-oriented, rather than effort-oriented.

[11] The blueprint does not perfectly reveal either the quality of the outcome or the effort spent on generating it. As clarified below, the actual choice of the blueprint for production is immaterial to the results.

[12] We assume that at t_1 it is suboptimal to unbundle development and production because of positive (expected) synergies between these two activities (which we do not explicitly model here, see for example **?**) and because it is optimal to reward innovation with informational rents from the production phase, biasing the selection in favor of the investor (as, e.g., in **?**). Nevertheless, as shown, at t_3 (after development), the buyer may deviate and assign production to a non-developing supplier.

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.[13] 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 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 eventually deprives one of the suppliers of his intellectual property right (IPR) embodied in his blueprint, by basing the production procurement on this very blueprint without ensuring that its developer will win the production contract.

Nevertheless, infinite repetition of the stage game allows the buyer and the suppliers to rely on relational contracting, by threatening to enact mutual punishments. In particular, the typical supplier threatens not to invest at all when selected in future procurement if the buyer deviates at t_3 by inviting $\tilde{n} > n$ suppliers to compete for production, and for that production takes the blueprint developed by one of the n selected suppliers. 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 in the procurement process (which are many in the specific industry of our data since the number N of potential suppliers is large).[14]

The observability of all investments at the end of time t_4 is clearly a strong as-

[13] 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.

[14] Our assumptions on the punishment involved are well reflected in the case study evidence we have collected prior to the questionnaire study. One of the authors conducted 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. A comprehensive account of the interviews is given in **?**

sumption, but similar results could be obtained assuming that the buyer only observes (exogenously) imperfect but informative signals of the investments.[15] We assume the buyer does not offer contingent payments such as discretionary bonuses.[16] 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 (see Section 5 below) we interpret δ, which is common to both the buyer and the suppliers, as an indicator correlated with the trust the participants in the game mutually associate with future co-operation and against present deviations.

3.2 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 does not invite more than the announced n suppliers to compete for the production contract, or deprive the suppliers of their intellectual property rights.[17]

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 $\pi(n) = \theta^e_{(2)}(n) -$

[15]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 would add an extra 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.

[16]This assumption is theoretically justified by **?**, in which it is shown that when the number of firms selected in the pool is $n < N$, as is the case for all observations in our data, discretionary bonuses are not sustainable in equilibrium because the buyer is able to defer paying the bonus and to replace the current supplier. We are not aware of any single case of public or private procurement in which such bonuses have been used, and the German car industry is no exception.

[17]As shown in MacLeod and Malcomson (1989) and Levin (2003), with unlimited liability and discretionary transfers, stationarity of contracts is without any loss of generality. In our automobile environment, liability limitations should not be an issue as we consider the production of one of many individual parts by the typical supplier.

$\theta^e_{(1)}(n)$, 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

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

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

$$w + \beta(n)\pi(n) \geq \frac{\underline{I}}{\delta} \tag{1}$$

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

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

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

$$\{v(\underline{I}) - nw - p^e(N)\} + [v(0) - p^e(N)] \frac{\delta}{1-\delta}$$

where the first term reflects the buyer's returns in the current period, and the second term her returns in the future stage games. 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

$$\delta \left[v(\underline{I}) - nw - v(0)\right] \geq p^e(n) - p^e(N) \tag{2}$$

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. All else given, when δ is small the buyer also has a stronger temptation to deviate, benefitting from the (expected) reduction in the cost of production.[18]

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

$$\begin{aligned}
&\max_{\underline{I},w,n} && [v(\underline{I}) - wn - p^e(n)] \tfrac{1}{1-\delta} && \\
&s.t. && w + \beta(n)\pi(n) \geq \underline{I}/\delta && (IC_s) \\
& && \delta\left[v(\underline{I}) - wn - v(0)\right] \geq p^e(n) - p^e(N) && (IC_b)
\end{aligned}$$

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

[18] We will show that the buyer's incentive compatibility constraint (2) 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 (2) would be $p\delta - p^e(N)$ and the constraint always satisfied. In passing, notice that the contractibility of n would eliminate the buyer's incentive constraint (2).

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 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 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,

$$w + \beta(n)\pi(n) = \frac{\underline{I}}{\delta}, \tag{3}$$

so that when δ increases, the buyer can afford to select 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 $(n, \underline{I})$ 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 $(n^*, \underline{I}^*)$. 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 (3), we can rewrite the buyer's per-period objective function as a function of the two main decision variables $\underline{I}$ and n,

$$H(\underline{I}, n) = v(\underline{I}) - n\frac{\underline{I}}{\delta} - \theta^e_{(1)}(n) \tag{4}$$

where the *actual cost of development* $n\underline{I}/\delta$ encompasses the cost of providing 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

$$v'(\underline{I}_n) = \frac{n}{\delta}. \tag{5}$$

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 $v(\cdot)$ is sufficiently concave, that is if the indirect effect is not too strong.*

In the Theoretical Appendix we illustrate this sufficient condition on the value of investment $v(\cdot)$. 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 $\underline{I}^*$.[19] This result contrasts with the intuition that trust requires an intimate relationship, that is, reduced competition.

3.3 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 (e.g. **?** or **?**). On the other hand, **?** or **?** stressed early 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

[19]The optimal transfer w^* is actually a residual variable determined by the binding constraint (3) , 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^*.

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 $\pi_2(n)$.[20] Since $\pi_1(n) \geq \pi(n)$, dual-sourcing guarantees a larger expected rent to suppliers. With an argument similar to that in the previous subsection, we obtain:

Proposition 3 *Assume the function $v(\cdot)$ 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 $v(\cdot)$ 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.

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

4 Detailed empirical analysis

Here we revisit the puzzle presented in Section 2 and go into detail regarding the underlying empirical identification strategy, now guided by our theoretical model.

Propositions 1, 2 and 3 tell us how δ affects the central choice variables of the procurement problem we are studying, that is the observed level of investment $\underline{I}$ by suppliers and the number n of competitors among suppliers chosen by the buyer, as well as the room for dual-sourcing at the production stage. A higher level of trust enables the buyer to "ask more" from a given supplier, either in terms of higher investment/quality, or by inducing tougher competition.

Our central measure of trust remains the "trust index", that is the arithmetic mean of the responses for the development and production stages.[21] Yet an issue associated with using the responses described above is that individuals may have idiosyncratic interpretations of what is *important* within 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 supplier selection. To address the potential measurement error, we normalise 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 use this as an alternative. This variable is our alternative measure, labelled *trust index (n)*.

Table 2 contains the summary statistics involving the two measures.

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 2: Trust Index Summary Statistics

First, we demonstrate how trust is related to relationship-specific investment. Then we consider the relationship between trust and the level of supplier competition induced by the buyer in her invitation to the procurement process, and also between trust and the buyer's preference for dual-sourcing in production.

[21] 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 the differences in the number of observations.

4.1 Trust and investment

The first prediction from our model is that higher levels of trust are associated with more relationship-specific investment by suppliers. Measuring supplier investment poses a serious challenge. As discussed in Section 2, we do not observe this investment directly, so we apply a proxy which is dependent on the quality of parts.[22] It is a standard interpretation of quality-related effort in the literature that supplier investment affects the failure rates of parts (**??**).

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%.[23] The points on the scale were interpreted as probabilities increasing from 0 to 100% in steps of 25%, which we use in a fractional probit specification. As a further robustness check, we specify a dummy as an alternative dependent variable. The dummy takes the value 0 only if no quality problems occur, that is if the lowest possible value 1 was reported for the quality issues question. The value 1 is therefore associated with a positive probability of quality problems. We estimate a probit regression using this variable.

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 manufacturer in assembling the final product also affects quality. The huge 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. To address the issue of possibly complementary effort or skill on the side of buyers (c), we introduce a dummy or fixed-

[22]The isolation of the supplier's buyer-specific investment poses well-known problems. In the present case, these problems are amplified by the fact that the specification should be car model-specific, and indeed, part-specific. In our case-study interviews, the suppliers stated that even they themselves have difficulties in specifying the development costs or the capital outlay for the production of a particular buyer-specific part.

[23]A potential drawback is the fact that the frequencies are self-reported, so that respondents may be tempted to under-report problems. To counter this, complete anonymity was guaranteed at the outset and upheld throughout the course of the study. In any case, it would lead to *underestimation* of any observed effects if more trust were to lead to a higher likelihood of admitting problems in the questionnaire.

effect for each of the eleven buyers in our regressions, that captures the buyer's effect on quality.

We choose the following (Fractional) Probit specification with robust standard errors. We denote as y_{ijs} the probability that quality problems arise for part i supplied to buyer j by supplier s, κ a constant, α_j the buyer fixed-effect, x_{ijs} the trust measure related to supplying part type i to buyer j by supplier s, and Z_{ijs} the respective control variables (dummies for the degree of technological sophistication and size of the part, as well as the interaction between the two dummies, and the supplier revenues in 2007).[24]

$$y_{ijs} = \kappa + \alpha_j + \beta * x_{ijs} + \gamma * Z_{ijs} + \epsilon_{ijs} \tag{6}$$

From our model we predict a negative coefficient for β: The likelihood of serious quality issues arising decreases in trust.

The results are in the first four columns of Table 3. Each estimate is presented using first the trust index and then the normalized trust index—labelled *trust index (n)*—that is the importance of trust relative to the importance of price.

Consider the Fractional-Probit regressions first. The coefficients of the trust variable are significantly negative, that is, higher levels of supplier trust are associated with less frequent quality issues. The size of the coefficients is relevant from an economic perspective. Increasing trust by one standard deviation coincides with a decrease in the probability of quality problems of between 24% (standard trust measure) and 10% (normalized trust measure).

The Probit estimation yields qualitatively the same outcomes, with somewhat smaller effects as we use the available information less efficiently. Here, an increase of trust by one standard deviation is associated with a decrease in the probability of quality issues of about 20% (standard trust measure) and 9% (normalized trust measure), respectively. Larger, more complex parts, systems and modules are more likely to suffer quality problems throughout.[25]

[24]The trust measure varies with variations in procurement issues across part categories. We can either include supplier revenues or supplier dummies. We choose revenues because they potentially include additional information on relative bargaining power.

[25]If we leave out the buyer dummies, the values are still significant, but slightly smaller in size. The difference between the two sets of values is in itself interesting. One explanation is that the buyer undertakes a complementary investment, and in its absence both the supplier's trust and the quality of parts may decrease. In other words, the effect of trust on quality (via the suppliers' investment) is then underestimated. We analogously observe assessments of the frequency of product related recalls.

Variables	Fractional-Probit♡		Probit ♠		IV♣	
trust index	**-.191****	-	**-.161****	-	-.070	-
	(0.011)	-	(.020)	-	(.103)	-
trust index (n)	-	**-.109***	-	**-.091***	-	**-.074****
	-	(0.075)	-	(0.067)	-	(.027)
tech. Soph. (D)	.026	.068	.025	.056	.013	.030
	(.877)	(.693)	(.833)	(.637)	(.663)	(.373)
size of part (D)	**.675*****	**.673*****	**.341*****	**.333*****	**.162*****	**.149*****
	(.000)	(.000)	(.003)	(.005)	(.001)	(.003)
interaction	-.055	-.069	.067	.089	-.067	-.059
	(.851)	(.813)	(.798)	(.730)	(.446)	(.497)
supplier revenues	-.006	-.007	.000	-.001	-.001	-.001
	(.386)	(.328)	(.996)	(.834)	(.611)	(.566)
const	-.162	-1.142	1.820	-.242	.492	.111
	(0.699)	(0.000)	(0.047)	(.557)	(0.021)	(0.093)
Buyer-FE (11)	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
1st stage F-value	-	-	-	-	8.69	10.34
Hansen-J	-	-	-	-	13.0	11.4
(p-value)	-	-	-	-	(.449)	(.579)
# observations	126	126	126	126	109	109
Ps-R^2	-	-	.155	.138	.255	.185

The table reports regression results for the following dependent variables: ♡ frequency of quality problems arising (in percent) – coefficients and (p-values) reported – ♠ probability of observing any quality problems – marginal effects at mean (except constant) and (p-values) reported – ♣ probability of quality problems arising (in percent), coefficients and (p-values) reported, trust indices instrumented by probability of buyer passing on supplier IPR. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 3: Trust and Investment: Probit, Fractional-Probit and IV regression results

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 lead to more conflicts between the parties, which could in turn negatively affect trust. Taking this into account, we also present the results of an instrumental variable approach using GMM. We instrument our trust measure using another item in the questionnaire. Suppliers were asked the following question: "*How often during the pre-development process does information leak, via the OEM to competing suppliers, in a way undesired by the supplier involved in the (pre-)development?*"[26] Answers were pro-

Performing the same exercise for these yields qualitatively identical results.

[26]This might potentially give rise to common method bias, especially if the same respondent answers both questions and is subject to the same perceptions. The instrument was in fact part of the pre-development section of the questionnaire, while the dependent variable stems from the series production section. Typically, different persons answered the two questions of interest, thus mitigating potential sources of bias.

vided on a 5-point scale anchored at 3, that is 50% of cases. The mean of the variable using the answer categories is 2.30, and the standard deviation is .97. For correlations with our trust measures and the other variables of interest, see Table 6 in the Empirical Appendix. For instrumentation, we use dummies for each observed answer category allowing for non-linearities.[27]

Our instrument pertains to the earlier history in the relationship, from the perspective of supplier representatives who are responsible for the pre-development stage, while quality issues arise during production. As one would expect, the instrument is strongly negatively correlated with our trust measure and yields high first-stage F-statistics. Nevertheless, due to the small number of observations, weak instrument-like issues remain. This caveat must be borne in mind in interpreting the results.[28]

With the IV estimation the coefficients are smaller than in the previous regressions, which is in line with our expectations of the reverse causality issue. An increase of the trust measure by one standard deviations causes a decrease in quality issues of around 8.8% (standard trust measure) and 7.2% (normalized trust measure), respectively.[29]

Overall, as standard theory would predict, we find a stable positive relationship between trust in a relationship and the part- and buyer-specific investment carried out by suppliers.

4.2 Trust and competition

We now return to the second, and more surprising, component of our puzzle. We observe the level of competition measured by the number of competing suppliers in the three phases: model-unspecific pre-development, model-specific development, and model-specific series production. From the existing relational contracting literature and the literature on trust in Japanese lean production, one would tend to predict a negative relationship between the number of competing suppliers and trust, especially in the latter two phases.[30]

[27] Answers to this question could reflect the buyer's deviation from the equilibrium path, involving another form of punishing the supplier for deviating passt behavior. This, however, would only strengthen the applicability of the answers as an instrument.

[28] According to **?**, as we would expect, the F-statistic indicates both small sample issues (15% and 20% maximal IV-size), as well as a remaining relative bias of around 10%.

[29] The higher F-statistic for the normalized trust measure indicates that normalization does indeed contribute to addressing measurement issues with regard to trust.

[30] For example, **?**, 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

Consider the different phases in the light of our model. In the earliest phase, that is pre-development, the investment by the supplier typically is not relationship-specific. There is no hold-up threat by the buyer and the mechanics of our model do not apply—as a result, there is no reason to expect a positive correlation between trust and competition. It is only in the later stages—development and series production—that we predict a positive association between the two measures from our model: higher trust enables the buyer to demand more from the supplier without violating his incentive constraint. We can test empirically how supplier competition in the different stages of production is associated with our trust measure.

We report OLS results below.[31] We denote as n_{ijs} the number of suppliers employed by buyer j for part i observed in the relationship with supplier s, κ a constant, α_j the buyer fixed effect, x_{ijs} the trust measure, and Z_{ijs} the vector of control variables including the investment level/quality level of the part.

$$n_{ijs} = \kappa + \alpha_j + \beta * x_{ijs} + \gamma * Z_{ijs} + \epsilon_{ijs} \tag{7}$$

From our theory, we expect a positive sign for β in the specification for development and series production, but not for the pre-development phase. Table 4 contains the results.

Corresponding to our theory, we find that our trust measure is strongly, positively and significantly associated with the number of suppliers in the development and the series production stages. For development, an increase of trust (standard index) by one standard deviation is related to an expected additional 0.40 suppliers; for the normalized trust index, the increase per standard deviation is around 0.18. This must be viewed in relation to the average number of suppliers in this stage, which is 1.52, so that the increases correspond to a 26 % and 12 % of the average number, respectively.

In series production, we also find a positive relationship between trust and producing firms, though the coefficients are smaller and not as strongly significant as in the

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)

[31] Since significant shares of the observations are at the lower limit of one supplier, we also performed Tobit as well as Probit regressions for the occurrence of multiple-sourcing. The results are qualitatively identical. The instrument used in the analysis of trust and investment, the frequency of the buyer disregarding the supplier's IPR in the past, is not exogenous with regard to the number of suppliers observed and thus cannot be employed here.

Variables	**Pre-Dev. ♠**		**Dev.♣**		**Ser. Prod.♡**	
trust index	-.108	-	**.318*** **	-	**.169***	-
	(.468)	-	(.009)	-	(.055)	-
trust index (n)	-	-.147	-	**.181***	-	**.170***
	-	(0.150)	-	(0.071)	-	(.073)
tech. Soph. (D)	.278	.293	**-.308***	**-.368****	**-.403*****	**-.429*****
	(.245)	(.213)	(.065)	(.033)	(.001)	(.001)
size of part (D)	.071	.071	.353	.356	**-.363*****	**-.331*****
	(.758)	(.749)	(.208)	(.208)	(.001)	(.001)
interaction	.029	.020	**-.711***	-.716	.179	.139
	(.932)	(.952)	(.098)	(.112)	(.320)	(.446)
supplier revenues	-.002	-.003	**.004*****	**.004*****	.008	.009
	(.667)	(.564)	(.001)	(.001)	(.166)	(.140)
const	2.578	1.983	-.587	1.045	.375	1.291
	(.001)	(.000)	(.387)	(.000)	(.380)	(.000)
Buyer-FE (11)	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
# observations	82	82	126	126	127	127
R^2	.226	.238	.266	.241	.228	.253

The table reports 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; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Trust and Competition: OLS-regression results

development stage. An increase of trust (standard index) by one standard deviation is associated with an increase in the number of suppliers by 0.20, while for the normalized index an increase by one standard deviation increases the number of suppliers by 0.16. Again, it is important to note the average number of suppliers employed at this stage in relation, which is lower at 1.20. By contrast, that relationship remains insignificant for the pre-development phase.

Our characterization of the different phases is corroborated by the signs and significance of the controls. Our standard controls, in particular technological sophistication and size of the part, do not play a significant role in the pre-development phase, reflecting the observation that the research in this phase follows a different set of rules. By contrast, as one expects from standard arguments, technologically sophisticated parts tend to be developed and produced—and sizeable parts produced—by significantly fewer suppliers.

Overall, the positive association of trust with investment and competition at the development phase, and with the number of producing firms, is consistent with the predictions of our theoretical model in Sections 3.2 and 3.3 above. Indeed, we account for several effects of trust on procurement within our structure for which we could not find a competing alternative.

4.3 Further robustness checks

We have carried out a set of further robustness exercises. First, towards controlling for countervailing effects on $\underline{I}$ and n in the buyer's optimization problem, we ran a simultaneous equation model in which we allowed for correlation of the error terms between each equation. Despite the lower number of observations, the results are qualitatively completely in line with what we observe in the previous subsections (see Table 8 in the Empirical Appendix).

Second, we addressed an obvious worry that the higher investment/quality observed in our regression could be compensated by the buyer with a higher contribution to the suppliers' development efforts, w. Our survey contains a question on the percentage of development costs that the buyer reimburses via a lump-sum payment. The distribution is strongly skewed, with 57% of suppliers reporting that only 10% or less of costs are compensated via a lump sum.

Corresponding to the worry above, one might expect that higher compensation would be associated with higher levels of trust. By contrast, we would predict from our model either the opposite relationship (for given values of the other two decision variables of the buyer) or possibly no effect (when the other two variables adjust in the optimum). Table 7 in the Empirical Appendix shows that higher levels of trust do not significantly affect—or are not significantly affected by—higher levels of compensation for R&D. This result is robust to a wide range of further alternative specifications.

Next, we introduced geographic characteristics as an alternative, clearly exogenous instrument. We used the federal state in Germany in which the suppliers' and the buyers' headquarters are situated, as well as the street distances between headquarters. One could expect a cultural affinity resulting in higher levels of trust if two firms have their headquarters in the same state. Distance, on the other hand, is not necessarily linearly associated with trust. In addition to the effect of cultural proximity, as distance increases, direct control of the opposite party may become more difficult, making trust more important. In fact, we observe (weak) positive correlations of our trust measure with same-state origin (correlation of .05) and distance (correlation of .12). To allow for a non-linear relationship of distance and trust, we used dummies for distance classes, with each bin composed of 100km. Neither measures allow for variation of trust at the relationship level. The IV-regressions using these instruments suffer from weak instrument issues. Yet the results are fully in line with our previous analysis. They are reported in Table 9 in the Empirical Appendix.

Finally, we ran regressions for the occurrence of quality problems, as well as for the number of suppliers in development, while "controlling" for the other relevant procurement variable, in the spirit of testing Proposition 1 more directly. The structure of correlations remains as predicted by our model (see Tables 10 and 11 in the Empirical Appendix).

5 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. **?**, **?**, **?** and **?**, among many others, use the classic Fisher-GM case or Asanuma's (**?**) case-based description of upstream supplier-buyer relationships in the Japanese automotive industry as examples. **?** uses the same case to motivate his survey of the relational contracting literature. Our evidence is based on a large-scale questionnaire survey and does not focus on a handful of cases.

Central to our analysis is the concept of a trust relationship. Any business relationship that does not resort to legal means of enforcement would, in colloquial terms, be referred to as based on trust: *"I will stick to a cooperative strategy if I trust that my opponent/partner does".* In this sense, trust can be seen as the basis for relational contracts. The notion is already highlighted in **?**, **?** and **?**, and appears with small variants in more recent contributions to the literature on relational contracting.[32]

Using questionnaire survey data involving first-tier suppliers from both Japan and the U.S., **?** examine empirically the determinants of these suppliers' trust in their main customer.[33] By contrast, we look both empirically and theoretically at the effects of variations in a given trust relationship between the typical supplier and each of his buyers.

[32] See **?** and **?** for a summary of this literature. As MacLeod (2007, p. 609) puts it: *"In a relational contract, one party trusts the other when the value from future trade is greater than the one period gain from defection."*; that is, when the discount factor is large in a model involving a repeated relationship.

[33] **?** provide a comprehensive survey of the trust issue in business relationships. See also **?** and **?**.

Furthermore, we focus on different issues, based on questionnaire survey information specific to the development and production phase as well as the type of part supplied.

In recent theoretical work on relational contracts, the discount factor is also regarded as the best indicator of trust in that environment. **?**, 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.[34] Accordingly, **?** 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. **?** 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. We also interpret the discount factor as an indicator of the level of trust in our relational contracting model.

Trust interpreted in this way is an optimizing concept, which does not encompass the multi-faceted sociological and psychological constructs that can also be associated with the term. **?** provides a discussion of this concept and alternative views. While we agree with **?**, among others, that there are good reasons to use such a view in more general contexts, a calculative interpretation linked to purely material 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 effect on choices and outcomes in organizations and countries.[35] While the experimental studies do focus on a concept of trust and on identifiable individual partners as the object of trust not unlike our study, most empirical studies are based on more general ideas and objects of trust, as indicated in the following question contained in the World Value Survey: "*Generally speaking, would you say that most people can be trusted, or that you have to be very careful in dealing with people?*" Answers to this question will be related to a much wider concept and unspecific object of trust, while our focus is trust in a

[34] They write: *"The discount factor is then a proxy for the trust level in the relationship. By studying the effect of variations in verification technology and the discount factor, we can gain insight into the relationship between court ability, explicit contracting, trust and relational contracting."* (p. 2193)

[35] An overview of the experimental and neuro-economic literature on the subject is provided by **?**. For the empirical studies of trust, see **?**, **?**, **?**, **?**, or **?**.

specific for-profit organization as part of a business partnership.

For what concerns the theoretical relationship between trust and competition, our paper is closest to **?** where the optimal relational contracting model of **?** is extended to the case of multiple competing agents (see also **?**). 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 questions.

To our knowledge, the only other empirical analysis of the relationship between trust and competition is **?**. 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 **?**'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 very presence of high trust in the relationship affords the buyer more competition between the suppliers.[36]

Regarding the negative association between competition and trust, see also Sako (1992), MacDuffie and Helper (1997), and references therein. It is also indicative that in Malcomson's (**?**) comprehensive survey of relational contracting, most papers involve bilateral contracting issues – and the few involving multilateral ones address cooperative, rather than competitive, relationships. McMillan and Woodrooff (1999) show empirically that a supplier and a buyer can rely more on non contractible dimensions (such as implicit trade credit) when the buyer has reduced access to alternative and competing suppliers. Helper and Levine (1992) argue that arm's length competitive supply relations were good to protect downstream oligopolistic rents from suppliers attempt to appropriate them, but the increase in competition among automakers, that is entry by Japanese car producers in the US, forced US manufacturers to move towards more efficient trust-based supply relationships.

Our paper is also related to the literature on the procurement of innovation.[37] The

[36]The tradeoff between competition and trust we derive in our model is similar, in spirit, to the tradeoff in the incomplete-contract model of **?**. See also the literature on the relationship between competition and the hold-up problem (**?????**).

[37]See **?** and **?** for surveys.

focus in that literature is typically on the optimal design of static mechanisms to elicit innovation, like auctions or contests. We focus instead on how the dynamic relationship between a buyer and his regular suppliers governs, through the shadow of the future, the supply of multiple, sequential and typically incremental innovations (new blueprints). In our model, informational rents from current and future production contracts are used to reward non-contractible investments in R&D – together with monetary transfers, as is the case in our data on the German car-manufacturing sector. Our setup is therefore consistent with **?**. Even in a static setting and without cost synergies between R&D and production stages, it is still optimal to use production contracts to reward the preceding non-contractible R&D investment that delivers the innovation, as happens in each stage of our dynamic game.

Finally, our analysis is related to the growing literature on managerial practice in manufacturing firms, and in particular to that relying on relational contracts.[38] **?** 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. **??** 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 in buyer-supplier relations.[39]

Within this literature, **?** analyze theoretically 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, and that when vendor-specific IT leads to fewer suppliers, repeated relationships become key to the governance of the supply chain. Specifically, if relationship-specific supplier investment increases, the number of suppliers decreases, and firms engage in more repeated relationships with those suppliers. We differ in the fact that we endogenize relationship-specific supplier investment and identify both theoretically and empirically the role of trust in long-term relationships, using our specific measure of trust. This allows us to directly assess the interaction between trust, competition and investment with very

[38]See the surveys by **?** and **?**, and references therein.

[39]See **?** for a survey of the few empirical papers that provide evidence of relational contracts on the basis of correlations between the discount rate and performance in a contractual relationship, or the use of formal, instead of relational contracts. They clarify that the discount rate (there proxied by the termination probability) should be correlated with the use of formal contracts only if these contracts are used as fallback options when an informal contract breaks apart.

detailed data on the bilateral relationships.

6 Concluding remarks

Trust is an important ingredient in almost all meaningful social and economic interactions. While, largely due to availability of data, most 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.

We show that higher levels of trust lead to higher relationship-specific investment and, more surprisingly, induce more competition amongst suppliers selected from a larger pool of potential suppliers, both in the development and production stages. Hence trust and the quasi-rents from limited competition are substitutes in terms of sustaining cooperative behavior—higher non-contractable investment—between the buyer and the sellers.

We then document empirically how buyers' and sellers' investment in mutual trust, characterized by their decision to forego short-term opportunities to appropriate rent, can pay off. Contractual relationships characterized by higher levels of trust are associated with significantly higher investment by suppliers, resulting in fewer failures and recalls of the parts supplied and final vehicles.

In line with our theoretical result, we also show that higher levels of trust are associated with the downstream procurer's decision to have a larger number of upstream suppliers compete in model-specific—and thus relationship-specific—upfront development towards the production contract, and its decision to set up production in parallel of the same part. We consider these results surprising, especially in view of the fact that our measure of "trust" in another party's behavior is not based on just one individual response, but instead on an aggregate of the responses of engineers and business managers in the same firm who focus on different facets of the relationship when asserting their level of trust in the other party, a particular automotive producer. In other words, higher levels of trust also benefit all parties involved in contractual relations by granting lower costs and smoother production.

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 strongly 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.[40] In particular, the representatives were in charge of developing key definitions used in the questionnaire. For example, substantial effort was dedicated to making sure that it was possible to control for differences in product characteristics.[41] For this, products had to be representative of one of four product classes:

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

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

[41]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 all buyers in clinical detail, 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.[42] The unit of observation used here is the supplier's perception of his interaction with the buyer specified for that part—thus including part-specific details from R&D to product markets, and with it part- (or product group-)specific differences in the buyer's procurement practices.

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.[43]

Returning to our data base, one questionnaire contains 185 questions and 150 sub-questions extending over all phases, including retrospective questions related to a given

[42] One outside buyer was also included, as a reference player. Conversely, each buyer was asked to evaluate in exactly the same detail her relationship with the first-tier suppliers, here aggregated for each product group in order to preserve supplier anonymity. In this study, we use only the suppliers' responses, because they are buyer-specific.

[43] 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.

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.

The questionnaires were filled in by supplier representatives in charge of development, production, or sales of the product, respectively; engineers; procurement, and sales officers.[44] 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.[45] Summarising, each observation describes one 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 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 information on 308 different relationships. The remaining 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.

This 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

[44]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 **?**.

[45]As a robustness check to this specification, we also ran our analysis for observations defined as the average questionnaire responses for a product type (instead of individual product) and customer. All results remain qualitatively unchanged.

available observations. The results overall remain qualitatively unchanged and tend, as one would expect given the higher number of observations, to be more significant.

Descriptive statistics

Table 5 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.
Prob. 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 5: Dependent and independent variables

Suppliers report that, on average, quality problems arise for about 1 in 6 (16%) part-specific relationships with a buyer. The number of suppliers competing during pre-development (2.18 on average) is substantially higher than the number of suppliers competing in the development of the specific blueprint for a part (1.52 on average). At the beginning of production, on average 1.20 suppliers are selected by the buyer. On average, about 28 % of the suppliers' up-front development costs are compensated as a lump sum by the buyers. As mentioned above, we observe that suppliers often complain about their IPR being leaked to other parties by the buyer without their assent. The associated question, which we use as an instrument for trust below, is reported on a five point scale anchored at 3. From this, we can derive that in about 32 % of relationships, suppliers complain about IPR being passed on by buyers.

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).[46] The interaction

[46]For a subset of our data, we observe the R&D cost share of parts. It is in fact significantly and

between the two captures effects that are specific to systems, which combine technological complexity and larger size. Finally, we introduce the 2007 revenues of the supplier in question as a proxy for supplier bargaining power.

Table 6 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. Note 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; we will use this as an instrumental variable for trust below.

substantially higher for components and systems (around 7.5%) than for commodities and modules (around 5.0%), but not statistically distinguishable within these groups.

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

Tables Robustness Checks

Variables	OLS ♠		Fractional-Probit♡		IV♣	
trust index	-.011	-	-.026	-	-.052	-
	(.781)	-	(.808)	-	(.619)	-
trust index (n)	-	-.005	-	-.009	-	-.095
	-	(.858)	-	(.912)	-	(.167)
tech. Soph. (D)	.022	.023	.069	.070	.017	.014
	(.714)	(.705)	(.703)	(.698)	(.788)	(.829)
size of part (D)	**.168***	**.168***	**.487****	**.490****	.157	.097
	(.053)	(.054)	(.030)	(.031)	(.110)	(.374)
interaction	-.105	-.103	-.271	-.267	-.072	-.036
	(.454)	(.460)	(.493)	(.498)	(.625)	(0.812)
supplier revenues	-.003	-.003	-.011	-.011	-.003	-.004
	(.189)	(.180)	(.136)	(.130)	(.137)	(.136)
const	.276	.221	-.630	-.760	.526	.219
	(.168)	(.003)	(.254)	(.000)	(.296)	(.014)
Buyer-FE	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
1st stage F-value	-	-	-	-	19.2	25.2
Hansen-J	-	-	-	-	16.3	14.1
(p-value)	-	-	-	-	(.129)	(.215)
# observations	106	106	106	106	93	93
R^2	.257	.268	-	-	.228	.169

The table reports regression results for the following dependent variables: ♠ reimbursement share in percent (percentage of development costs that the buyer reimburses via a lump-sum payment), coefficients and (p-values) reported; ♡ reimbursement share in percent, coefficients and (p-values) reported; ♣ reimbursement share in percent, coefficients and (p-values) reported;* significant at 10%; ** significant at 5%; *** significant at 1%

Table 7: Trust and Reimbursement: OLS, Fractional-Probit and IV- regression results

Variable	Coefficient	(p-value)	Coefficient	(p-value)
Equation 1 : likelihood of quality issues				
trust index	-.039**	(.044)	-	-
trust index (n)	-	-	-0.032**	(.017)
size of part (D)	.195***	(.000)	.187***	(.001)
tech. soph. (D)	-.018	(.618)	-.013	(.726)
interaction	-.034	(.724)	-.025	(.793)
supplier revenues	-.001	(.565)	-.001	(.558)
const	.346	(.003)	.137	(.015)
Equation 2 : compensation percentage				
trust index	-.023	(.549)	-	-
trust index (n)	-	-	-.013	(.662)
size of part (D)	.150*	(.086)	.150*	(.092)
tech. soph. (D)	-.018	(.764)	-.014	(.808)
interact	-.001	(.995)	.002	(.989)
supplier revenues	-.001	(.566)	-.002	(.558)
const	.330	(.088)	.211	(.002)
Equation 3 : # of suppliers development				
trust index	.340***	(.006)	-	-
trust index (n)	-	-	.199*	(.070)
size of part (D)	.222	(.469)	.226	(.484)
tech. soph. (D)	-.338*	(.071)	-.387**	(.042)
interaction	-1.091**	(.021)	-1.139	(.029)
supplier revenues	.045***	(.000)	.045***	(.000)
const	-.658	(.715)	1.123	(.000)
Covariance(e.quality issues,e.compensation)				
	.003	(.523)	.003	(.504)
Covariancev(e.quality issues,e.suppliers dev.)				
	-.016	(.186)	-.018	(.178)
Covariance(e.compensation,e.suppliers dev.)				
	-.030	(.248)	-.032	(.213)

Customer fixed effects included, 84 observations, coefficients and (p-values) reported, dependent variables: likelihood of quality issues arrising (eq. 1), lump-sum reimbursement share for development costs (eq. 2) and number of suppliers during development (eq. 3); * significant at 10%; ** significant at 5%; *** significant at 1%

Table 8: Estimation results : Simultanous equation models

Variables	**IV-Quality Issues** ♠		**IV-Suppliers Dev.**♡	
trust index	**-.112****	-	**.709****	-
	(.018)	-	(0.014)	-
trust index (n)	-	**-.077****	-	**.619****
	-	(0.033)	-	(0.011)
tech. Soph. (D)	.001	.025	-.278	**-.455****
	(.962)	(.416)	(.123)	(.034)
size of part (D)	**.144*****	**.138*****	.440	**.536***
	(.001)	(.003)	(.114)	(.065)
interaction	-.025	-.020	**-.748***	**-.803***
	(.757)	(.789)	(.063)	(.070)
supplier revenues	.001	-.001	**.039*****	**.041*****
	(.692)	(.460)	(.002)	(.003)
const	.688	.103	-2.441	1.341
	(0.003)	(.083)	(.085)	(0.000)
Buyer-FE	**yes**	**yes**	**yes**	**yes**
1st stage F-value	2.84	5.34	2.84	5.34
Hansen-J	9.52	10.60	7.08	4.92
(p-value)	(.484)	(.390)	(.718)	(.896)
# observations	126	126	126	126
Ps-R^2	.146	.136	.189	.088

The table reports regression results for the following dependent variables: ♠ probability of observing quality problems – coefficients and (p-values) reported – ♡ number of competing suppliers employed in development – coefficients and (p-values) reported; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 9: Robustness Check: Alternative Instrumentation using Distance Between Company HQs and Location in same Federal State

Variable	Coefficient	(p-value)	Coefficient	(p-value)
trust index	**-.184****	(.017)	-	-
trust index (n)	-	-	-.100	(.107)
# sup. dev.	-.024	(.714)	-.047	(.460)
tech. soph. (D)	.020	(.909)	.052	(.765)
size of part (D)	**.682*****	(.000)	**.686*****	(.000)
interaction	-.069	(.816)	0.095	(.744)
supplier revenues	-.005	(.466)	-.005	(.478)
const	-.175	(.678)	-1.091	(.000)
Buyer-FE	**yes**	-	**yes**	-
# obs	126	-	126	-

Table 10: Robustness check: Fractional probit results. Dependent variable: probability of quality issues arising – controlling for number of suppliers in development

Variable	Coefficient	(p-value)	Coefficient	(p-value)
trust index	**.311*****	(.010)	-	-
trust index (n)	-	-	**.174***	(.083)
prob. qual. iss.	-.193	(.683)	-.341	(.488)
tech. soph. (D)	**-.306***	(.069)	**-.363****	(.037)
size of part (D)	.384	(.233)	.411	(.209)
interaction	-.717	(.100)	-.727	(.111)
supplier revenues	**.042*****	(.001)	**.044*****	(.001)
const	-.524	(.432)	1.093	(.000)
Buyer-FE	**yes**	-	**yes**	-
# obs	126	-	126	-
R^2	.266	-	.243	-

Table 11: Robustness check: OLS regression results – Dependent variable: # of suppliers during development – controlling for probability of quality issues arising.

Theoretical Appendix

Proof of Proposition 1.

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

$$w + \frac{\theta^e(n) - \theta^{e\prime}(n)}{n} = \frac{I}{\delta}$$

We have

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

with a slight abuse of notation, we obtain

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

The result in this case follows from the observation that

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

together with

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

and

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

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

$$w = \frac{I}{\delta} - \pi(1) \tag{8}$$

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

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

and

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

To identify the effect of an increase of δ on n in the case $n = 1$ we need to compare the buyer objective function in the case $n = 1$ and $n = 2$. For a given level of investment I, 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:

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

which can be written as:

$$[E(\theta) - \theta^{e\prime}(2)] \geq \frac{I}{\delta}$$

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

Proof of Proposition 2.

Note 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 $v''(\cdot)$ 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 $n > \tilde{n}$. The solution to program $\mathcal{P}$ with n is preferred to $\tilde{n}$ if (where we denote with $\underline{I}_n$ and $\underline{I}_{\tilde{n}}$ the associated optimal level of investments defined by (5)):

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

or equivalently

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

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

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

and with a Taylor approximation

$$v'(\underline{I}_{\tilde{n}})\underline{I}_{\tilde{n}} - v'(\underline{I}_n)\underline{I}_n = [v''(\zeta)\zeta + v'(\zeta)]\,(\underline{I}_{\tilde{n}} - \underline{I}_n) = \left[\frac{v''(\zeta)}{v'(\zeta)}\zeta + 1\right]\frac{(\underline{I}_{\tilde{n}} - \underline{I}_n)}{v'(\zeta)}$$

so that, finally,

$$\text{sgn}\left\{\frac{d}{d\delta}\left\{\left[v(\underline{I}_{\tilde{n}}) - \frac{\tilde{n}\underline{I}_{\tilde{n}}}{\delta}\right] - \left[v(\underline{I}_n) - \frac{n\underline{I}_n}{\delta}\right]\right\}\right\} = \text{sgn}\left\{\left[\frac{v''(\zeta)}{v'(\zeta)}\zeta + 1\right]\right\}. \tag{9}$$

Clearly if $v''(\cdot)$ is sufficiently negative the sign r.h.s. of (9) 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 (5) 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 (5) 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 (5) is smaller when n^* increases than when it remains constant.

Proof of Proposition 3.

From the binding suppliers' incentive compatibility constraint, as in (1), and coherently assuming that w is 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:

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

We now compare dual-sourcing to single-sourcing, the latter being now associated with a buyer's expected (per-period) payoff:

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

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:

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

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

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

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

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

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

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:

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

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

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

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

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

Following the same steps as in the proof of Proposition 2, it now follows immediately that for any given δ if the function $v(\cdot)$ is sufficiently concave when the buyer is indifferent between single- and dual-sourcing:

$$H_d(\underline{I}_d^*, n_d^*) = H(\underline{I}^*, n^*) \tag{10}$$

we have

$$n_d^* \underline{I}_d^* > n^* \underline{I}^* \tag{11}$$

Moreover, the envelope theorem implies that, as in Section 3.2 above, the effects of δ on the optimal value of the buyer's per-period payoff under both dual- and single-sourcing are:

$$\frac{\partial H_d}{\partial \delta} = \frac{(n_d^* \underline{I}_d^*)}{\delta^2}, \qquad \frac{\partial H}{\partial \delta} = \frac{(n^* \underline{I}^*)}{\delta^2} \tag{12}$$

If $v(\cdot)$ 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 $v(\cdot)$ is sufficiently concave, at the threshold where the buyer is indifferent between single- and dual-sourcing—that is condition (10) is satisfied—from (11) and (12) above, when δ increases the buyer moves from optimally choosing single-sourcing to choosing dual-sourcing. In other words, dual-sourcing is more likely the higher is the level of δ.