

Trust, Competition and Innovation:

Theory and Evidence from German Car Manufacturers*

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Abstract

We develop a simple theoretical model of a long term buyer-supplier relationship with non-contractible buyer specific R&D investment, and derive predictions on the effects of trust and competition on suppliers' investment and buyers' procurement strategies. We address these issues empirically using unique survey data on individual buyer-supplier relationships in the German automotive industry. Consistent with the model's predictions, higher levels of trust are associated with higher investment levels – but also with more competitive procurement: trust and rents from reduced supplier competition in the procurement process emerge as substitutes both in theory and in the data.

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1 Introduction

Trust is a key ingredient of social life, and of business transactions alike. Trust facilitates informal relational contracts which can potentially achieve higher surplus than legally enforceable ones. If an agent trusts that he will be treated fairly by his trading partner, he will be more willing to invest in the relationship, and thereby increase surplus and efficiency.

Business relationships and transactions are often repeated episodes of sequences of exchanges, in which case trust-based relational contracts tend to be the most efficient governance instruments for non-contractible dimensions. The procurement of parts for complex products, such as automobiles, is a particularly interesting example. Indeed, some scholars such as ? regard General Motors' inability to counter the competition by Toyota in the last decades as largely due to the inability of GM's management — at times represented by its chief procurer Ignacio Lopez — to fully grasp the importance of collaborative management practices, by not establishing and maintaining long-term relationships with both suppliers and employees.

According to the “German model”, suppliers are typically in long-term relationships with producers and, in contrast to the US, undertake a large part of the R&D investments leading to innovations. A reverberating shock to this system was delivered by the decision of Volkswagen to poach Ignacio Lopez, who subsequently implemented arm's length cut-throat competition procurement practices (PICOS), disregarding trust-based management practices that were previously in place. *In the short run*, this decision proved to be highly profitable, so that it was imitated by other producers and spread through parts of the industry. By expropriating upstream quasi-rents, this strategy undermined the suppliers' incentives to undertake relationship-specific investments into innovation and quality *in the long run*, which are a crucial to the success of the “German model”.

In this paper we first theoretically analyze the complex interaction between trust-based relational contracts, competition among suppliers, and upstream incentives to undertake non-contractible R&D investment. Using data on the German automotive industry after the events described above, we are then able to empirically test the predictions of the model. We show as a first result that if trust between a supplier and a manufacturer is high, the relational contract is associated with a high level of specific

non-contractible investment in R&D on the part of the supplier. This relationship is compatible with several existing theories; to our knowledge, though, we are the first to provide empirical evidence based on relationship-specific measures of trust and investment.

Perhaps more surprisingly, our second main result shows both theoretically and empirically, that the higher the level of trust, the larger the number of competing suppliers employed by a manufacturer in procuring the R&D and design of a part. In other words, higher levels of trust are associated with more intense competition between suppliers in the procurement process.

Our data set is derived from a unique survey conducted under the auspices of the German Automotive Industry Association (VDA) on the relationships between important first tier suppliers and their buyers, i.e. all ten German automobile manufacturers (plus one outsider). The data set is unique in at least two respects. First, it reflects a critical phase in the industry with regard to buyer-supplier relationships. Second, due to their interest in finding a resolution, the respondents to the questionnaire survey were uniquely prepared to participate and disclose details of their relationships.

In particular, our data set allows us to identify the long term implications of the shock to the system generated by Lopez's unexpected arrival and aggressive attempt to shift production procurement towards prices close to marginal costs – without consideration for the up-front R&D efforts undertaken by the suppliers.¹ Due to the considerable short run cost savings that were realized, these methods were closely observed and in some cases adopted by some firms in the German automotive industry, although the experiment was cut short due to mostly unrelated legal issues.² Other automotive manufacturers understood the relationship-destroying implications, however, and were more cautious or even fully refrained from adopting the methods. This generates the variation that allows us to empirically investigate the effects of different procurement mechanisms used by the manufacturers in the German automotive industry using cross-sectional data.

Upstream buyer-supplier relationships in automobile production, in particular in

¹One of the schemes Lopez employed was to procure innovative designs at costs born by the suppliers, to choose the best design, and to use this as the basis for an aggressive purely cost-oriented production procurement without compensating the developer of the winning design (??, Ch. 11).

²Lopez was ousted from his role at VW not long after he had arrived, because GM claimed that he had misappropriated trade secrets upon his departure from the company. Yet core members of his team are still employed at VW.

Germany, are an extraordinarily good field for such a study, for several reasons. The most important is that there is plenty of room for hold-up and expropriation. As indicated above, upstream suppliers in Europe, in particular in Germany, are, in contrast to the U.S. car manufacturing industry, responsible for much of the ground-breaking research, which is then adapted to the specific needs of individual car-models.³ The resulting, often highly complex intermediate product exhibits features that are buyer-, and even car-model-specific. This specificity provides ample room for hold-up. Since in the final product, the automobile, there are strict complementarities and model-specific interfaces between all contributing parts, efficiency considerations necessitate the early and lasting co-operation between the different agents involved in the design and production of the parts of an automobile. This is implemented under the auspices of the car-manufacturer, and is associated with a superior market power vis-à-vis its suppliers.⁴ In all, when contracting with an upstream supplier, the car-manufacturer is confronted with a clear trade-off between attaining the desired quality level for the individual part, and the desire to extract rents by enforcing lower prices.

Our data set allows us to explore, in detail, the nature of contracts between car-manufacturers and suppliers, taking the contracting environment, and contracting partners' evaluations of their relationship into account. In particular, we have evidence of the suppliers' perceptions of contracting relationships with individual automotive producers they develop and produce for.

As to the transactions involved, we distinguish between individual products taken from one of four categories differentiated by complexity and size. The contracting relationship with individual car manufacturers is then documented for all development and production phases.

To organize our empirical analysis, we develop a theoretical model of the procurement relationship. A buyer repeatedly procures a product which involves the development of a blueprint requiring buyer specific and non-contractible R&D investment by the supplier(s), followed by the production phase. There are several firms capable of developing such a blueprint of producing the part. The potential suppliers differ in production costs unknown to the buyer. After the development phase, a supplier is selected for production, possibly through a competitive auction. The buyer chooses the amount of

³In terms of R&D intensity, ? position the European suppliers between the U.S. and the Japanese.

⁴See ? for a detailed account.

investment he desires from the suppliers, invites one or more of them to invest and develop a blueprint, and then selects the blueprint and supplier, to whom the production contract will be offered.

We focus on relational contracts featuring contractible and non-contractible components. In equilibrium the buyer restricts herself to selecting one of the suppliers that invested at the development stage for production, using informational rents as compensation for the non-contractible investment. A deviation by the buyer (inspired by what Lopez did) consists in opening competition for the production contract to all potential suppliers, independently of whether they undertook any investment. In turn, the supplier(s) can punish the buyer by refusing to invest in the future. Conversely, the typical supplier can deviate by not investing at the level desired by the buyer. In turn, the buyer can punish that deviation by excluding the supplier from future procurement.

We derive several predictions from this simple model. First we re-establish the result, and with it, provide a framework for the empirical analysis, that higher levels of trust lead to higher relationship-specific investment. Second, we show that an increase in trust can be associated with more competition in the procurement process induced by the car-manufacturer. The reason is that trust and expected quasi-rents from limited competition are substitutes in terms of sustaining cooperative behavior (investment and connected reward) between the buyer and the sellers.

With the data described above, we then provide evidence consistent with the prediction of the model that higher levels of trust lead to higher relationship-specific investment, proxied by lower failure-rates of the respective parts that reflect associated quality. We also provide evidence of our second prediction that trust and competition between upstream suppliers and the downstream firm are not mutually exclusive: suppliers' higher trust in their buyer, the downstream firm, is associated with significantly more intense suppliers' competition at the development stage as induced by the buyer's procurement scheme.

The remainder of the paper is organized as follows. After briefly reviewing the theoretical, experimental and empirical literature in Section ??, we develop, in Section ??, the theoretical framework, and derive our hypotheses on the effects of trust on vertical relationships. In Section ??, we first introduce the survey data on which our empirical analysis is based. We then discuss our measure of trust and evaluate what it captures. In Section ?? we present our empirical analysis on how trust between manufacturers

and suppliers is related to suppliers' investment and buyers' sourcing decisions. We conclude with Section ???. Proofs are relegated to the Theoretical Appendix. An Empirical Appendix contains descriptive statistics and robustness checks.

2 Literature Review

With our paper we contribute to the growing literature on managerial practice in manufacturing firms and in particular on that relying on relational contracts.⁵ ? make a strong case for relational contracts as the crucial managerial practice to explain Toyota's and other Japanese car manufacturers' ability 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.⁶

A business relationship that does not resort to legal means of enforcement would in colloquial terms be interpreted as based on *trust*. In this sense, trust can be seen as the basis for relational contracts: *I will stick to a cooperative strategy if I trust that my opponent/partner does*. This notion is already highlighted in ?, ? and ? and appears with small variants in other contributions to the literature on relational contracting summarized by ? and ?.⁷ Recent relational contracts theories also regard the discount factor as the best indicator for trust in that environment. In their model of relational contracts with endogenous verification ? identify trust and the discount factor and perform comparative statics on the latter to understand how their results change when different amounts of trust are present.⁸ Accordingly, ? defines trust as the belief that a party has on the opponent's ability to resist the temptation to cheat in a relational contract parameterized by her discount factor.⁹ ? defines the discount factor of the

⁵See the surveys by ?, ?, and references therein.

⁶See ? for a survey of the few empirical papers that provide evidence of relational contracts on the basis of correlations between the discount rate, or fallback options, and the performance in a contractual relationship, or the use of formal contracts (as opposed to relational contracts). Among other observations, they clarify that the discount rate (there proxied with 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.

⁷As 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.*

⁸They 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)

⁹In his model, when agents begin a relational contract with an unknown partner, each party may face

principal as a proxy for his trustworthiness, and studies how belief on the principal's discount factor, i.e. trust, evolves along the relationship.

In our model, we also interpret the discount factor as an indicator of trust in a long term relationship. An agent, understanding her partner's long-term self-interest, trusts him not to yield to short-term temptations. Trust interpreted this way is an opportunistic concept. It clearly does not encompass all multifaceted sociological and psychological constructs that can also be associated with it.¹⁰ However, we believe this interpretation to be appropriate in a model of relational contracting between firms, and, indeed, in the corresponding business relationships we analyze in our empirical exercise.¹¹

Because of this specific, yet relevant interpretation, 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.¹² 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 of the empirical studies are based on more general ideas and objects of trust, as reflected 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 specific for-profit organization as a business partner.

As to the nexus between trust and competition, our paper is closest to ? where the optimal relational contracting model of ? is extended to the case of multiple compet-

an adverse selection problem if potential partners vary in their discount factor, i.e. in their willingness to honor a relational agreement. An agent is then said to be trustworthy if his discount factor makes him capable of resisting the temptation to defect from a relational contract, while the level of generalized trust in the economy is defined as the probability that in equilibrium an unknown partner resists the temptation to defect and performs according to the relational contract. Trustworthiness is therefore a property of preferences innate to the agent, modeled as her discount factor, while generalized trust is an endogenous belief about the behavior of others generated by the equilibrium interaction of individual preferences and the structure of the economy.

¹⁰See ? for a discussion and alternative views.

¹¹The object of trust in our survey is an automotive manufacturer (OEM), a large and rather impersonal business enterprise, and the interviewed subjects are professional managers answering within their professional role. The variation we observe and use in managers' reported trust towards different OEMs is therefore likely to be mainly driven by the economic characteristics of the OEMs, like their past behavior and their management style, more than by the psychological or sociological forces dominant in interpersonal relationships.

¹²A rich overview on the experimental and neuro-economic literature on the subject is provided by ?. As to empirical studies, see ?, ?, ?, ?, ?, among many others.

ing agents. 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 limit moral hazard, but at the risk of inducing collusion among these agents against the principal. Our theoretical analysis, however, deals with a very different stage game where suppliers invest in non-contractible R&D before knowing whether they will be selected to produce the good.

Regarding the empirical relationship between trust and competition, the only study known to us is by ?. 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 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 allows the buyer to induce more competition between the suppliers.

Finally, our paper is also closely related to the literature on the procurement of innovation.¹³ The focus in this 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 the monetary transfers, as is the case in our data on the German car-manufacturing sector. Our setup is therefore consistent with ?. There, the authors show that 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 it happens at each stage of our dynamic game.

3 A theoretical model of innovative products

In each period a buyer (she) needs to procure an intermediate product. This process entails first the development of the blueprint of such a product, which requires an investment I , for example an R&D investment embodied in a blueprint, by the supplier —

¹³See ? and ? for surveys.

unobserved to the buyer within the current period — and subsequently the production of the intermediate product. 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 $N \geq 1$ firms capable of investing and supplying the intermediate product. Investment is non-contractible. Its cost is sunk and normalized to I for I units of investment. After the investment phase, a supplier (he) is selected for production. We assume for simplicity that production cannot be shared by more than one producer. 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.

Investment I is considered buyer specific, so 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 $1 \leq n \leq N$ of firms including their identity that are invited to develop the blueprint of the intermediate product and to compete for its production. 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 the supplier obtaining the production contract at t_3 and paid at t_4 will be selected.

t_2 (*Development*): Each selected supplier i incurs sunk cost I_i towards his investment I_i ; the transfer w is paid by the buyer to each of the n firms.

t_3 (*Selection*): The buyer invites \tilde{n} firms to compete for the production contract according to the mechanism he committed to in phase t_1 . Each of these suppliers' production cost θ_{it} is realized. The buyer employs the committed mechanism to select 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} with a blueprint chosen

by the buyer among those developed and receives the transfer p from the buyer. At the end of the stage game the buyer observes the investment of the n firms invited to the development phase of the procurement process.

Notice first that, for simplicity, we assume that the buyer's commitment to a transfer w and to the mechanism used to allocate the production contract is contractible and, as such, enforceable by courts. The mechanism the buyer commits to for selection differs depending on whether $\tilde{n} > 1$ or $\tilde{n} = 1$. If she chooses $\tilde{n} > 1$ and thus opens procurement to competition, then the mechanism she commits to at t_1 is a second price auction, and the price p for production is determined by that auction.¹⁴ If she chooses $\tilde{n} = 1$, she simply quotes the desired minimal investment level \underline{I} , pays the transfer w , awards the selected firm the production contract and commits to a 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 of investment I_i of any firm i , as well as the number of suppliers admitted at the selection process at t_3 , are not contractible. Nevertheless, infinite repetition of the stage game allows the buyer and the firms to rely on relational contracting. In particular, if at the end of t_4 the buyer observes that a firm l has deviated and invested $I_l < \underline{I}$, he will exclude that firm from future procurements, possibly replacing it with another firm amongst the $N - n$ firms previously excluded. Conversely, if the buyer deviates at t_3 by inviting $\tilde{n} > n$ suppliers to compete for production, then all N firms in the industry observe this deviation at the end of t_4 and will no longer trust the buyer, implying that they will not invest in the future if selected. Although the buyer is uninformed about θ_{it} we assume, for simplicity, that suppliers observe the realization of all production costs.¹⁵

Clearly the observability of all investments at the end of time t_4 is a strong assumption, but similar results could be obtained assuming that the buyer only observes (exogenously) imperfect signals of the investments, possibly different for the blueprint that has been actually used in production.¹⁶

We assume the buyer does not offer contingent payments such as discretionary

¹⁴One could equivalently employ a first price auction, since we are assuming suppliers cannot collude.

¹⁵Incomplete information between the suppliers would not qualitatively alter our results, at the cost of complicating the expressions of the informational rents earned by the suppliers.

¹⁶Non-observability of the investments in blueprints not used in production would add an extra incentive compatibility constraint to avoid 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.

bonuses.¹⁷ The discount factor across different phases of the same stage game is one and is δ across different stage games.

3.1 Relational procurement with R&D investment

In this subsection we characterize the main properties of a relational procurement equilibrium. We consider stationary relational contracts where the n suppliers, selected by the buyer, develop the required blueprint by undertaking investment $I \geq \underline{I}$ (> 0), and the buyer invites no more than the announced n firms to compete for the production contract.¹⁸

In the development phase, each of these suppliers decides how much to invest, anticipating his expected informational rent $\beta(n)\pi(n)$ associated with the production contract in this stage game. We denote $\beta(n)$ the probability that a given supplier will obtain the production contract among the n firms, and $\pi(n)$ the expected rent accruing to the 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 $\pi(n) = \theta^e(n) - \theta^{el}(n)$, where $\theta^e(n) = E[\theta(n)]$ is the expected cost of the second (most) efficient supplier, and similarly $\theta^{el}(n)$ the expected cost of the 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 $p = \theta(n)$, where $\theta(n)$ 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 $\pi(1) = p - \theta^{el}(1)$, where $\theta^{el}(1) = E(\theta)$ and p is the price the buyer commits to at t_1 .¹⁹

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

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

¹⁷This assumption is theoretically justified in ?, in which we show 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 of the buyer's ability to defer paying the bonus and replacing the current supplier). Empirically, 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.

¹⁸As shown in MacLeod and Malcolmson (1989) and Levin (2003), with unlimited liability and discretionary transfers, stationarity of contracts is without any loss of generality.

¹⁹The (expected) rent necessary to induce investment is then delivered through the sum of monetary payments $w + p$.

If instead the supplier decides to deviate and to invest less than required, then he knows that the buyer will notice this deviation at the end of the stage game and exclude the supplier from all future procurements. In this case it is clearly optimal for the deviating firm to set $I = 0$. His expected profit is then

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

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

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

is satisfied. Any selected supplier chooses investment \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 (minimal) investment \underline{I}/δ . This cost is high if δ is small. In this case, all else given, the typical supplier faces a stronger temptation to cheat in the investment phase, and cash in the informational rent in the production phase.

Let $p^e(n) = \theta^e(n)$ be the price the buyer expects to pay for production when the buyer 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 $\tilde{n} > n$ firms to compete. In this case it is optimal for the buyer to choose $\tilde{n} = N$, that is to invite all available suppliers even 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 $p^e(N)$ instead of $p^e(n)$. In this case no supplier will ever invest in the future, hence the buyer will also set the transfer $w = 0$, so that the buyer's expected discounted payoff from deviating is

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

where the first term reflects the buyer's returns in the current period, while the second term his returns in the future stage games.²⁰ The buyer prefers not to deviate by inviting

²⁰We assume, for simplicity, that a supplier can produce with a blueprint developed by another firm at no additional cost.

more than the selected n firms to participate in the production auction if the incentive constraint

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

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. When δ is small the buyer has, all else given, also a stronger temptation to deviate, and thus to benefit from the (expected) reduction in the cost of production.²¹

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

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

This program shows, on the one hand, that if the buyer wants to induce high investment, he has to account for the typical supplier's incentive not to deviate, here represented by (IC_s) . This puts a limit on \underline{I} . Also, increasing the number n of competing suppliers reduces the cost of production, and with it, the expected price $p^e(n)$ paid by the buyer. At the same time, it 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 because the higher cost of production that she has to bear relative to the case in which she invites all firms to compete, $p^e(n) - p^e(N)$ in (IC_b) , decreases in n . Clearly, a higher discount factor δ helps to better control both, the buyer's and the suppliers' incentives.

It is immediate to see that an optimal solution requires the supplier to always adjust the transfer w so that the incentive constraint (IC_s) is binding. Suppose not, then the buyer could reduce w , thus increasing both her objective, and relaxing her incentive constraint (IC_b) . From the fact that the transfer w guarantees that (IC_s) is binding,

²¹Although we will show that the incentive compatibility constraint of the buyer (??) does not affect our ensuing analysis, we notice that whenever the buyer invites just one supplier $n = 1$, the deviation of 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 (??) would be $p\delta - p^e(N)$ and the constraint always satisfied.

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 larger number of suppliers n ,*
- (ii) *a higher level of investment \underline{I} .*

In particular, since (IC_s) is binding:

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

the buyer can afford a higher number n of competing suppliers (at given w and \underline{I}) when δ increases, which implies a larger set of suppliers to select from, and with it a lower expected production cost. An analogous reasoning applies to result (ii). The simple, yet general, idea is that a higher discount factor δ grants the buyer some “slackness” dealing with suppliers’ incentives which in turn translates into better procurement terms, i.e. more competition (i.e. lower cost of production) and higher investment (higher value for the final product).

The *overall* effects of a change of δ on *actual* terms of procurement is more articulate than the comparative statics of Proposition 1. Imagine, for example, that an increase of δ induces a higher level of investment \underline{I} , as contemplated in point (ii) of Proposition 1. The overall effect of δ on the number of firms must thus account not only for the *primary effect* described in point (i) 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 all the three optimal procurement instruments (n, w, \underline{I}) is thus more complex because it requires us to account for the primary effects of Proposition 1 and for all indirect effects. Towards that we need to solve the procurement program of the buyer \mathcal{P} and verify the effect of δ on optimal procurement $(n^*, w^*, \underline{I}^*)$. Rather than providing a full solution of program \mathcal{P} , we exploit some of its properties so as to verify under what conditions the general idea stated above persists, by which the “slackness” of a higher discount factor still induces the buyer to procure with more suppliers, higher investment and lower transfers.

The binding incentive constraint (IC_s), implies that the transfer w is implicitly defined by (??), and that we can rewrite the buyer's per-period objective function as a function of the two main decision variables \underline{I} and n :

$$H(\underline{I}, n) = v(\underline{I}) - n\frac{\underline{I}}{\delta} - \theta^e(n). \quad (4)$$

We can then show that, whatever level of investment \underline{I} , some numbers of suppliers n may not be viable because they do not satisfy the buyer's incentive compatibility constraint.²² Hence, in the following we will restrict to and explicitly consider only those number of suppliers that satisfy constraint (IC_b).

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 per period buyer's payoff $H(\underline{I}, n)$. For a given n , we indicate with \underline{I}_n the maximizer of $H(\underline{I}, n)$, implicitly defined by

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

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

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

In the Appendix we also illustrate the precise condition on the value of investment $v(\cdot)$ guaranteeing that the indirect effect is not too strong, so that the higher the discount factor, the higher is the optimal level of investment requested by the buyer, as well as the optimal number of competitors. 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}^* .²³

²²Indeed, for a given n , constraint (IC_b) can be rewritten as $H(\underline{I}, n)\delta \geq v(0)\delta + (1-\delta)p^e(n) - p^e(N)$. If this constraint is not satisfied at the optimal level of investment that maximizes the buyer's per-period objective function $H(\underline{I}, n)$, then the buyer can never credibly procure with n firms.

²³The optimal transfer w^* is actually a residual variable determined by the binding constraint (??) and this expression 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

3.2 Empirical strategy: Mapping the theory into our data

We now specify the predictions from our theoretical analysis that we bring to the data. Key to our analysis is the interpretation of δ , the discount factor, as an indicator of trust. We study bilateral long-term relationships between suppliers and automotive manufacturers (OEMs), with the possibility of opportunistic behavior. The discount factor indicates the relative importance of the rents from future interactions compared to today's profits.

Our dataset is cross-sectional — we observe the status of the relationship at one point in time — so that fluctuations in interest rates do not play a significant role. Where we would expect and do observe considerable variation, though, is in the (subjective) likelihood of future opportunistic behavior. If one party to an agreement is considered more likely to deviate in the future, then the other party will discount future rents from the relationship more steeply, which is equivalent to a lower level of δ . The experience from the early to mid 1990s in the German automotive industry has demonstrated both to the industry and to researchers which form such a deviation could and can take. If trust is the expectation that the other party will behave in the desired and agreed fashion, while the possibility exists to do otherwise, then higher levels of trust should be associated with higher values of δ in the language of our model.²⁴

Propositions 1 and 2 tell us how trust affects the central choice variables of the procurement problem we are studying, that is the observed level of investments by suppliers I and the number of competitors among suppliers n . A higher level of trust enables the OEM to “ask more” from a given supplier, either in terms of higher investment/quality, or by inducing tougher competition (and thereby reducing expected informational rents of the suppliers). We measure these parameters either directly or proxy for them in our empirical application as follows. Competition between suppliers, as chosen by the buyer's procurement strategy, is directly observed in our data via the number of suppliers invited to the development stage and allowed to compete for production. This is n in our model above.

Relationship-specific investment I is not directly observable in our data, however. As a proxy, we use a measure that is both proposed in the theoretical literature, e.g. by ?,

relationship between δ and w^* .

²⁴We discuss the issue of the determinants of trust and how to measure the concept in greater detail in Section ?? below.

and used in practice in the automotive industry.²⁵ This is the frequency of part failures, which is both highly relevant to the buyer and considered to be (inversely) related to the suppliers' effort and the quality of the blueprint.

Then, how can we translate Propositions 1 and 2 into our data so as to be tested? The propositions state that higher δ , higher levels of trust, should be associated with levels of investment that are more profitable for the OEM levels, and competition in the procurement process as induced by the OEM, holding all else constant. It is immediately obvious that it is not possible to control for all procurement choice variables in any single regression, since by our theory they are interdependent and simultaneously part of the OEM's procurement strategy. Given that we have a cross-sectional data structure, it is unfortunately not feasible to find exogenous instruments for each of the variables of interest.

To tease out the effects of trust, we choose the following strategy. First, to make best use of our observations, we individually study the relationship between trust and each of the two variables of interest (with a number of controls). Second, we analyze a simultaneous equations model, in which we allow for correlation between error terms. What makes us confident of this chosen approach is the fact that the main procurement variables are, in fact, uncorrelated or only weakly correlated.

We summarize the predictions we derive from our model, in the following two hypotheses.

Hypothesis 1 *More trust is associated with higher relationship specific investment by suppliers, resulting in lower failure rates of parts.*

Variants of the first hypothesis concentrating on supplier opportunism are well known since ?. Yet to the best of our knowledge, they were never brought to a test that involves the relationship between identifiable subjects as partners in a contract.

Our next result that involves the effect of trust on the level of competition induced by the OEM is perhaps more complex and surprising. In a large part of the relational contracting literature, it is argued that depending, for example, on the enforceability of complex clauses, competitive (arms-length) contracts are the opposite of relational contracts, which appear more closely related to trust. Indeed, competitive and relational

²⁵See, for example, the detailed descriptions in ?.

contracting typically are considered mutually exclusive.

On that basis one might expect that a supplier-OEM relationships governed by trust should be associated with less competition being induced by the OEM. Our theoretical model predicts that the opposite should be true if we are in a world governed by long term relationships: the higher the level of buyer-supplier trust, the higher the level of competition that can be induced by the buyer in the procurement process.

The intuition behind this result is simple. From the buyer's perspective, restricting competition in the procurement process is costly, as it involves higher (expected) payments as information rents to the chosen supplier. Yet the buyer's ability to induce more competition is limited by the level of supplier's investment she might be able to induce through the suppliers incentive constraint. This constraint is relaxed with a higher level of trust, and this enables the OEM to pick a higher level of competition. All of this can be interpreted as trust and rents (to suppliers) from reduced competition being substitutes, or, equivalently, trust and competition being complements. Thus

Hypothesis 2 *Higher trust is associated with more intense competition between suppliers, as initiated by the OEM in the procurement process.*

In what follows, we bring these hypotheses to the data and test whether they are reflected in what we observe in the German car industry in recent years.

4 Data and Descriptive Statistics

4.1 Data Source

Our data originate from a unique online questionnaire survey study that we conducted under the auspices of the VDA between Fall 2007 and Summer 2008 on the upstream supplier-buyer relationships in the German automotive industry. The questionnaire design was based on the results of pilot case studies we performed in Spring 2007, in which we had conducted numerous interviews with high ranking executives in the industry, with a focus on tier 1 suppliers' marketing and automotive producers' purchasing efforts.²⁶

The theory we have developed above represents the institutional environment we observed in these case studies. This applies in particular to our formulation of the formal

²⁶For the qualitative results of this case study, see ?.

and the informal components of the contracts involved. Along the case study interviews, we saw first detailed performance specifications as summarized, in our model, by a single scalar, required (minimal) investment \underline{I} . Most notably, these performance specifications are *not* part of the framework contract containing the verifiable components. Second, we learned about cases in which the automotive producer would exclude suppliers in later procurement auctions, after opportunistically and unilaterally deviating from the investment schedule proposed by the buyer. Third, we were informed about situations in which the automotive producer deviated from his promise to not increase the number of suppliers invited to the production procurement process. Indeed, initiatives to this effect were at the core of the changes initiated by Ignacio Lopez. And fourth, we were informed about cases in which suppliers refused to invest into buyer specific R&D, when the buyer had deviated from his promise to restrict the number of suppliers admitted to the procurement auction, which is represented by the punishment strategy in the model.

While the design of our study reflects the specifics of location and sector, we are confident that it contains essentials valid in many other empirical situations, in particular the procurement of parts for the production of airplanes. Other interesting examples involving the combination of unverifiable innovation and verifiable production components in supply contracts are developed by Gilson et al., leading law scholars in the field of law and economics, on the importance of relational contracting and its implementation, in a series of articles (?, ?, ?, ?).

Beyond the case studies, the questionnaire data provide us with a uniquely detailed view of the relationship between OEMs and their first-tier suppliers.²⁷ Each participating supplier was asked to evaluate its relationship with each OEM it supplied in Germany in clinical detail, separately for all phases of product development and production, and multiple products that were representative for each of the four product classes of an established industry classification. The four product classes are:

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

(High-tech) Components: physically small but technologically sophisticated (e.g. elec-

²⁷Indeed, we conducted this survey within a window of time that was unique in two respects: first, the Lopez affair had introduced substantive variation in the procurement processes adopted by the German automotive producers; and second, to some extent induced by that affair, the respondents were pressed to improve the buyer-supplier relationship, and thus willing to spend the required days in filling the questionnaires.

tronic 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 stabilization programs).

The questionnaire consisted of more than 300 questions covering all functions within the firms directly or indirectly critical for the development of the procurement relationships. In total, more than 1,500 questionnaires were filled in by competent engineers, procurement, and sales officers. A participant first would have to indicate his function within the company out of the following seven: *pre-development* (“basic” technological research, not model-specific technological development), *vehicle development* (car-model specific technology adaptation), *series production*, *quality control*, *sales*, *logistics*, *after-market production*.²⁸ Finally, the participant was asked to choose a product for which he had the necessary know-how, as well as the customers he worked with. For each product and customer, he would then answer the set of questions suited to his function within the company.

In the present study, we focus on the responses provided by the suppliers. We consider as *one observation the set of answers to the questionnaire by one supplier for a given product and customer*.²⁹ Thus, each observation describes one supplier’s view – i.e. the aggregate view of the employees that were asked to fill the questionnaire – of the relationship with a given OEM for a product representative for one of the product classes. Potentially, therefore, different individuals, working for the same supplier, contributed answers to the different parts of the questionnaire. Hence, in order to obtain observations that covered as much of the questionnaire as possible, we merged the answers received from a given supplier for a given product and customer over all functions to cover all aspects of the relationship.³⁰

²⁸For a detailed description of the individual functions and the automobile development and production process, we refer to ?. The characteristics of Pre-development, Development and Series Production are discussed in Section ??.

²⁹Therefore, for multiple questionnaires concerning the same part and customer, we took the averages of responses. As a robustness check to this definition, 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.

³⁰Whenever parts of questionnaires overlap, we use the arithmetic mean of the answers.

Note that observations for individual items can be missing for for two reasons: First, the questionnaire was not necessarily completed for each product within each function of a company. Second, participants occasionally skipped individual questions. Therefore the number of observations over questions differs, as reported in the descriptive statistics below. In addition to this, not every supplier cooperated with every OEM in every product class. This means that we have to make a choice with regard to the composition 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 these most important regressions.³¹

4.2 Descriptive Statistics

With the underlying questionnaire we sought to depict complex supply relationships in hitherto unmatched detail. Therefore, we first introduce – perhaps taking up more room than usual – the selection of variables we focus on, in the hope to shed some light on the basic forces and tensions that are at play between manufacturers and their suppliers.

4.2.1 Participating Companies, Class Specification and Bargaining Power

On the OEM side, all automotive manufacturers producing in Germany participated in the survey, 7 producers of passenger cars and 3 truck makers. Upstream 13 suppliers active in the German market completed the survey on 11 OEMs (the 10 participating automotive manufacturers plus one outside player). The supplier sample is strongly biased towards large participants, with average revenues in 2007 of 9.4 billion Euro (std. 12.4). Even the smallest participant posted revenues of more than 700 million Euro. This is reflected by the self-reported European market shares for the individual products in our sample: This was provided on a 5-point scale with an average of 3.74 (std. 0.94), which translates into a share of more than 25% of the European market.

One might worry that the larger suppliers are able to exert monopoly power over OEMs for some of the parts we study. As a result we might pick up the effects of

³¹As robustness checks, we also ran each regression for all available observations. The results overall remained qualitatively unchanged and were, as one would expect given the higher number of observations, in tendency more significant.

differentials in relative bargaining power vis-a-vis OEMs instead of differentials in trust, as discussed in the theoretical model above. Using data from a separate commercial database,³² we verified that each product in our sample was produced by at least two firms active in the German market. Further, we use proxies to control for relative market power in our regressions, as this may clearly affect bargaining strength and the OEM’s outside option, as described below.

The first proxy for relative bargaining power is company size, therefore we include the 2007 revenues of suppliers in the regressions. The second set of proxies is related to the product class or type specification introduced above, which are strongly related to relationship specificity: Suppliers were asked to estimate the R&D-share of total costs for the particular part being analyzed. The item is measured on a 5-point scale provided in 5% increments — ranging from less than 1% to more than 15%. Table ?? displays the statistics for the R&D cost shares by product class.

Cost share R&D	Mean (Std. Dev.)	Min	Max	Obs
<i>Systems</i>	3.00 (0.96)	1	5	42
<i>Modules</i>	2.54 (0.78)	1	5	44
<i>Components</i>	3.10 (0.89)	2	5	53
<i>Commodities</i>	2.45 (0.63)	2	5	91

Table 1: Cost share R&D of total cost by product type.

The average R&D cost shares for the high-tech parts systems and components are significantly higher – by about 2.5 percentage points than for modules and commodities.³³ The averages are around 7.5% for the high-tech parts and only 5% for commodities and modules, so the difference is very substantial. To use as many of our observations as possible, we capture the technological sophistication of a part (and, in a sense, the specificity of the relationship) by introducing a dummy variable which takes the value 1 if the part is a system or high-tech component. We also introduce a dummy taking the value 1 for systems and modules, in order to account for potential price differences due to the sheer size of the part. To account for potential system-specific effects, we introduce an interaction term between the two dummies.³⁴ Finally, to capture remaining effects of

³² “Who supplies whom” collected by supplierbusiness.com.

³³ Pairwise sample mean comparison tests reveal significant differences between systems/components and modules/commodities, but not within each of these groups. Among these two groups the hypothesis of equal means cannot be rejected, which is in line with the product class specification.

³⁴ In what follows, in particular in the regression tables, these variables are labeled “tech. soph.,” “size of part” and “interaction,” respectively.

market structure, we include “customer fixed effects,” that is dummies for each of the individual OEMs in the regressions.

4.2.2 Product Development Life-cycle and Supplier Competition

In our theoretical model, we depict two different stages in the development life-cycle of a product: The development stage, in which suppliers invest to create a blueprint, and the production phase, in which the surplus is generated and allocated. While clearly a simplification, this structure is mirrored in our data. Indeed, we observe three distinct phases in the product life-cycle: *pre-development*, *development* and *series production*. Below, we briefly sketch these phases and describe how we use them in our empirical approach.

In *series production*, suppliers work with existing blueprints and completely designed (or existing) tools to produce the part in question. The product and services can be clearly specified through contracts, determining in detail, for example, acceptable failure rates and delivery conditions. None of this is possible in the model-specific *development* phase. While the desired functionality of a part can be described, highly complex interfaces with other parts (often under development simultaneously) cannot be specified *ex-ante*. Blueprints for the part do not exist at the beginning of the design phase, indeed they are the outcome of such a phase. The evolution of interfaces in the course of the part’s (and other parts’ simultaneous) design poses limitations to precise specifications in *ex-ante* contracts; this requires a continuous cooperative process. *Pre-development* covers 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. For example, 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. Pre-development often involves fundamental research, which makes it even harder to write enforceable contracts on the expected outcomes.³⁵

How do the OEMs’ procurement decisions differ over the different phases? Parallel to the theoretical model, we asked how many competing suppliers worked on the product in question within each of the design and production stages. For this set of questions, the

³⁵Overall, it is to be expected that contracts in the earlier phases are less specific, and rely on enforceability by repeated relationships, while contracts written in the production phase are more specific and rely on enforceability by the courts. See ? for experimental evidence on a similar question.

development stage was further subdivided into the four sub-phases (starting with the earliest): product planning, product specification, concept development and detailed development. Detailed development generates the final blueprint — this is what we interpret as the investment period in our theoretical model. For series production, we observe the number of suppliers at series start, after 1-2 years and after more than 2 years.

For pre-development on average more than two (2.29) suppliers compete.³⁶ This number stays about constant in the first three stages of development, before it significantly *decreases* for the last development phase down to 1.51.³⁷ It reaches its nadir at the beginning of series production with 1.20, before it increases again to 1.59 two years into production.³⁸ How can we interpret these results? During pre-development, the OEMs have multiple hand-picked suppliers work in parallel on the designs. The most promising approach is brought into the development process. As the contractual reimbursement for pre-development work is on average below 60% of the actual costs, whether or not the company is awarded a subsequent development contract, there is a strong incentive for suppliers to do everything possible for their preliminary design to be selected. An analogous process is repeated again for the development process, resulting in the specific blueprint. With this, the quality uncertainty is substantially reduced, given that firms are generally certified through stringent quality assurance processes. In production, fewer suppliers with higher volumes promise the highest economies of scale and the steepest learning curve. In addition, obtaining a sole production contract is the carrot used to incentivize suppliers in the previous design and investment process. Therefore the number of suppliers drops significantly at production start, in most cases down to a sole producer. Once the learning curve effects have been realized, the OEM can start to bring additional suppliers in.

These considerations are supported by a second set of observations. The respondents were asked to specify how often different procurement strategies are employed by the OEM for the product class in question in each of the different stages.³⁹ For

³⁶See Table ?? in the Appendix.

³⁷See Table ?? in the Appendix.

³⁸See Table ?? in the Appendix. This is in line with Che and Gale (2003).

³⁹Note that there is substantial variation in this measure as the pre-development, development and production of parts are often procured separately. In addition, production is frequently procured anew for each new series of a given model. There may be a new procurement process every 18 to 24 months, and different strategies could be used at different points in time.

pre-development, the options offered were *preselection of a specific supplier* and *procurement among a limited number of suppliers*, each on a 6-point scale from 1 (never) to 6 (very frequently). For development and series production, *open procurement* was added as a further option. From the above, we would expect a shift from relational to more arms-length contracting over the three phases and the results clearly support this hypothesis.

For pre-development, OEMs are significantly more likely to contract with specific suppliers (mean 4.43) than to go through a limited competitive procurement process (mean 3.95, t-test for difference of means significant at 1% level).⁴⁰ In contrast to this, pre-selection of suppliers is significantly less likely both for development (mean 3.06) and series production (mean 2.98).⁴¹ For development, the OEMs are significantly more likely to procure among a limited number of suppliers (mean 5.18), so there is a clear shift to more market-based interactions from pre-development to development.⁴² Similarly from development to series production, where procurement among a limited number of suppliers grows less important (mean 4.55), but there is a significant increase in the use of open procurement (2.44 instead of 1.97).⁴³

4.3 Measures of Trust

Trust is a sensitive concept which has proven to some degree elusive to attempts at explanation and measurement by economists. Existing studies have mostly employed either experimental/behavioral evidence, or subjects' answers to variations on the question "Can other people be trusted in general?", so the addressees of trust were not specified. In contrast, our data has the advantage that it is relationship-specific. We ask representatives of company *A* about their specific evaluation of the trust relationship with company *B* with regard to the interactions concerning a (type of) product in three ways, each with a slightly different emphasis:

- 1) *What is the importance of trust for your firm's decision to initialize a pre-development with the OEM?*

⁴⁰See Table ?? in the Appendix.

⁴¹See Tables ?? and ?? in the Appendix, respectively.

⁴²See Table ?? in the Appendix.

⁴³See Tables ?? and ?? in the Appendix.

- 2) *How do you evaluate mutual trust between OEM and supplier with respect to honoring each others' intellectual property rights?*
- 3) *Please evaluate the importance of mutual trust between the supplier and OEM for the OEM's supplier selection (respectively for each of the 3 product developments stages).*

These questions were subject to a lengthy discussion by a team consisting of representatives of the senior management of both buyers and suppliers. As the fallout from the business practices introduced to Germany by Lopez was the main focus of the overall undertaking, the definition of trust related questions required a particularly elaborate discussion. In a separate appendix,⁴⁴ we show in detail that the resulting measures are strongly positively correlated with each-other. Further, we study by which measures of OEM behavior, such as aggressive price re-negotiations, they are affected. In addition, we perform a factor analysis to demonstrate that significant shares of the variation in the measures can be explained by a single underlying factor. In the analysis below we use the third measure, in our view the most consistent of these measures both in terms of the phrasing of the question as well as the results of the factor analysis.

These questions were posed in a particular context: Suppliers were asked to evaluate the OEM's supplier choice criteria on a six-point scale from 1 (no relevance) to 6 (very important), for each stage of the development and production process, i.e., pre-development, development and series production. One item, our main variable of interest, was mutual trust between supplier and OEM. Suppliers were also asked to evaluate the importance of price on the same scale. Our preferred measure of trust is the arithmetic mean of the answers to the importance of trust items. The measure has a mean of 4.81, a minimum of 1.5, a maximum of 6 and a standard deviation of .81, with 309 observations. In the tables below, this variable is represented as *trust index*.

One might be tempted to ask why the questions were specified in terms of *importance of trust* rather than *trust* directly. The rationale was to avoid personalized responses. An issue with this type of response item is that individuals have idiosyncratic interpretations of what is *important*. In one major robustness-check, we normalize by taking the differences between the two (i.e., the relative importance of trust vs. price) and using

⁴⁴Available at: *Trust Appendix*.

this as an alternative. This variable is represented as *trust index (n)*.⁴⁵ The identical trust questions were also posed to OEMs in our questionnaire – with the crucial difference that they did not give relationship-specific answers, but instead evaluated their trust relationship with a “generic” supplier.

Figure ?? depicts both the assessments of individual suppliers regarding the different OEMs, as well as how each of these sees their relationship with generic suppliers. The figure underlines the different sources of variation in our data: On the one hand, trust by suppliers differs substantially across OEMs. This likely results from variations in Lopez’ influence on the OEMs’ procurement behavior. But in addition to this, the level of trust across suppliers with respect to the same given OEM can differ substantially. In our empirical approach in the following, we will use both of these sources of variation to identify the effects we are interested in.

Figure 1: Sources of variation in the trust measure.

Individual assessments and the average of trust in each OEMs from the perspective of suppliers, as well as the OEMs’ average view of trust in their relationship with generic suppliers.



⁴⁵Also, we performed the regressions below using the individual measures instead of the arithmetic mean. The results are qualitatively the same, though significance levels vary a bit due to the differences in the number of observations.

5 Empirical Analysis

In this section, we test the hypotheses resulting from our theory using this trust measure. Each question is related to central aspects of the buyer-supplier relationship: First we study how trust is related to relationship specific investment, as proxied by the reliability of the part. Then we study the role of trust with regard to suppliers' compensation for the part specific development costs. And finally, we consider the relationship between trust and the level of supplier competition induced by the OEM in its invitation to the procurement process.

There is one important caveat in the context of investment. Due to the cross-sectional structure of our data set, determining the direction of causality is an issue. One can make the argument that higher investment by suppliers leads to higher levels of trust in the OEM: Less investment by the supplier may lead to more conflicts between the parties, which in turn negatively affects trust. We apply an instrumental variable approach to explore the issue of causality more closely.

The compensation of suppliers is a highly sensitive issue, which is of considerable strategic importance. In fact, obscuring production and development costs is considered a central battleground between suppliers and OEMs, at least in the US auto industry, as ? illustrate in detail. Therefore, while we are fortunate to observe an estimate of the development cost share reimbursed by the OEM, these results have to be taken with a grain of salt.

With regard to the intensity of supplier competition, it is immediately clear that an argument with regard to causality is difficult in a cross section.⁴⁶ Especially in the mostly observed range between 1 and 2 suppliers, the higher level of competition may enable (mostly undesirable, from the perspective of the supplier) behavior on the side of the OEM that is impossible in a one on one relationship. Therefore we would consider a positive relationship between competition and trust, as predicted by our theory, a surprising and remarkable result, even if one can “only” show correlation.

Despite these limitations of the cross-section available to us, it is in our eyes important to remember: With our relationship specific and highly detailed data we probably come as close as until now possible to the empirical specification of the nexus between the trust relationship and our variables in question.

⁴⁶What we would optimally like to use would be exogenously caused regime shifts over time.

5.1 Trust and Investment

Hypothesis 1 from our model states that higher levels of trust should be associated with more relationship specific investment by suppliers. Measuring supplier investment poses a serious challenge. As discussed above, we do not observe product-specific investment directly, so we apply a proxy which is dependent on the quality of parts.⁴⁷ It is a standard interpretation of quality related effort in the literature that supplier investment affects the failure rates of parts (see, for example, ?).

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%.⁴⁸ Therefore the points of 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 robustness check, we specify an alternative dependent variable which takes the value 1 only if no quality problems occur, i.e., if the lowest possible value 1 was reported for the quality issues question. We estimate a probit regression using this variable (note that the signs of the coefficients should be opposing for the two regressions).

Our questionnaire allows us to study an issue on which it is usually tremendously hard to gain any traction for the following reasons. Typically, severe difficulties arise when trying to assess under-investment-related quality issues empirically, as a) the observed failure rates of cars cannot necessarily be linked to individual parts, b) the diligence of the manufacturer in assembly of the final product also affects quality and c) if quality problems are diagnosed and solved before the parts are installed, this is generally not observable. The huge advantage of our questionnaire is that the responses are part-specific, which addresses issue a). The phrasing of the question addresses issue c), as it was meant to include all of the development and production phases involving the part in question. By including customer- or OEM-effects in the regressions, we address issue b).

⁴⁷It is well known that the specification of buyer specific investment by suppliers poses problems. In the present case, these problems are amplified by the fact that the specification should be model, and indeed, part specific. In our qualitative 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 part.

⁴⁸A 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, this would lead to *underestimation* of an effect, if more trust would lead to a higher likelihood of admitting problems in the questionnaire.

We choose the following (Fractional) Probit specifications with robust standard errors: y_{ij} denotes the probability that quality problems arise with part i at OEM j , κ is a constant, α the customer fixed-effect, and Z represents the control variables (dummies for the technological sophistication and size of the part, the interaction term, and the supplier revenues in 2007).

$$y_{ij} = \kappa + \alpha_j + \beta * trust_{ij} + \gamma * Z_i + \epsilon_{ij} \quad (6)$$

Our hypothesis predicts a positive coefficient for β – the likelihood of quality issues is decreasing in trust. The results can be found in Table ???. Notice that due to the definition of the dummy, the effects in these regressions move in opposing directions and have to be interpreted accordingly.

Finally, as discussed above, there is a potential issue of reverse causality. To address this, we implement an instrumental variable approach (GMM). We instrument our trust measure by another questionnaire item.⁴⁹ Suppliers were also 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?*⁵⁰ The source of endogeneity that we would like to address is the following: One might be worried that quality issues (resulting from lower investment) might cause cracks in the trust relationship, instead of the lack of trust leading to lower investments. Our instrument is exogenous to this mechanism for two central reasons: First, it addresses issues arising at an earlier stage in the development process. Second, it inquires after behavior on the side of the OEM that is detrimental to the supplier’s interests, but not vice-versa. As one would expect, the instrument is strongly negatively correlated with our trust measure and yields a first-stage F-statistic larger than 20. Nevertheless, due to the relatively low number of observations, some weak instrument-like issues could remain. This slight caveat must be borne in mind in interpreting the

⁴⁹One might argue that this gives rise to a common method bias, as the same respondent answers both questions and is subject to the same perceptions. In the case of the questions used by us, the instrument was in fact part of a different part of the questionnaire, pre-development (instrument) instead of series production (dependent variable), so that in most cases, it was different persons answering the two questions of interest.

⁵⁰Answers provided on a 5-point scale 1-very rarely, 5-very frequently, anchored at 3-50% of cases. Mean of the variable is 2.24, standard deviation 0.95. For correlations with our trust measures and the other variables of interest, see the pairwise correlation table in the Appendix. As the instrument, we use dummies for each observed answer category.

results.⁵¹

Variables	Probit [♠]		Fractional-Probit [♡]		IV [♣]	
trust index	.161**	-	-.191**	-	-.070	-
	(.020)	-	(0.011)	-	(.103)	-
trust index (n)	-	.091*	-	-.109*	-	-.074**
	-	(0.067)	-	(0.075)	-	(.027)
tech. Soph. (D)	-.025	-.056	.026	.068	.013	.030
	(.833)	(.637)	(.877)	(.693)	(.663)	(.373)
size of part (D)	-.341***	-.333***	.675***	.673***	.162***	.149***
	(.003)	(.005)	(.000)	(.000)	(.001)	(.003)
interaction	-.067	-.089	-.055	-.069	-.067	-.059
	(.798)	(.730)	(.851)	(.813)	(.446)	(.497)
supplier revenues	-.000	.001	-.006	-.007	-.001	-.001
	(.996)	(.834)	(.386)	(.328)	(.611)	(.566)
const	-1.820	.242	-.162	-1.142	.492	.111
	(0.047)	(.557)	(0.699)	(0.000)	(0.021)	(0.093)
OEM-FE	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

♠ probability of *not* observing quality problems, marginal effects at mean (except constant) and (p-values) reported; ♡ frequency of quality problems arising (in percent), coefficients and (p-values) reported; ♣ probability of *not* quality problems arising (in percent), and (p-values) reported; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 2: Trust and Investment: Probit, Fractional-Probit and IV regression results

The results of the regressions can be found in Table ??.⁵² Consider the results of the Probit estimation first: The coefficients of the trust variable are indeed significantly positive, 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 by 9% (normalized trust measure, std. dev. of 1.04) to 20% (standard trust measure, std. dev. of .79).⁵³ In the fractional-Probit regressions, we find the same

⁵¹According to ?, the F-statistic is associated with between 15% and 20% maximal IV-size, with a remaining relative bias around 10%.

⁵²We analogously observe assessments of the frequency of product related recalls. Performing the same exercise for these yields qualitatively identical results.

⁵³If we leave out the OEM dummies, the values are still significant, but smaller in size. The difference between the two sets of values is in itself interesting. One explanation is that the OEM undertakes a complementary investment, in its absence both the supplier's trust and the quality of parts may decrease.

qualitative picture, with slightly higher effects of trust. An increase of trust by one standard deviation would be associated with a decrease in the probability of quality issues by about 24% (standard trust measure), and 10% (normalized trust measure), respectively. Larger, more complex parts, i.e., systems and modules, are more likely to suffer quality problems.

The results of the IV-estimation (using past misbehavior of the OEM with regard to the supplier’s IPR as an instrument) indicate that one can consider the effect of trust on quality as causal; 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) or 7.2% (normalized trust measure), respectively.⁵⁴ As described above, due to the low number of observations, this result has to be taken with a grain of salt.

Overall, we conclude that the evidence from the results supports our first hypothesis: As far as investment can be measured by the (inverse) frequency of quality problems, higher levels of trust are associated with higher levels of investment by the supplier.

5.2 Trust and Transfers for Development Costs

The second hypothesis to be tested empirically concerns the relationship of trust and transfers, w , from OEMs to suppliers as compensation for development costs. In our survey, we have a direct way to measure this, with the corresponding question asking for the percentage of development costs that the OEM reimburses via a lump-sum payment. On average, in our sample, suppliers report that 30.5% of development costs are reimbursed in this way, with a standard deviation of .284. The distribution is strongly skewed, with 57% of suppliers reporting that only 10% or less of costs are compensated via a lump sum.

We estimate the following linear probability and fractional probit specifications with robust standard errors: w_{ij} denotes the share of costs reimbursed as a lump-sum for part i produced for OEM j , κ is a constant, α is the customer fixed-effect, and Z represents the control variables (dummies for the technological sophistication and size of the part, the interaction term, and the supplier revenues in 2007). For completeness, we also

In other words, the effect of trust on quality (via the suppliers’ investment) is then underestimated.

⁵⁴For the full sample, the coefficients are indistinguishable in size, but more significant. The higher F-statistic for the normalized trust measure indicates that normalization does indeed contribute to addressing measurement issues with regard to trust.

include the results of instrumentation analogous to the previous section, though the sample is even smaller.

$$w_{ij} = \kappa + \alpha_j + \beta * trust_{ij} + \gamma * Z_i + \epsilon_{ij} \quad (7)$$

Intuitively, one might expect that higher compensation would be associated with higher levels of trust. Our model, on the other hand, would predict either the opposite relationship (for given values of the other two decision variables of the OEM) or possibly no effect (when the other two variables adjust). We present the results in Table ??.

Variables	OLS ♠		Fractional-Probit♡		IV♣	
trust index	-.010 (.802)	-	-.022 (.837)	-	-.050 (.638)	-
trust index (n)	-	-.007 (.814)	-	-.013 (.870)	-	-.090 (.198)
tech. Soph. (D)	.021 (.735)	.021 (.727)	.066 (.715)	.067 (.711)	.016 (.799)	.014 (.833)
size of part (D)	.142* (.100)	.141 (.106)	.417* (.064)	.416* (.068)	.134 (.172)	.079 (.465)
interaction	-.013 (.929)	-.011 (.939)	-.004 (.912)	.000 (.999)	.014 (-.927)	.037 (0.802)
supplier revenues	-.005* (.093)	-.005* (.089)	-.015** (.050)	-.015** (.048)	-.005* (.058)	-.005* (.059)
const	.287 (.254)	.236 (.002)	-.609 (.269)	-.724 (.001)	.529 (.297)	.234 (.007)
OEM-FE	yes	yes	yes	yes	yes	yes
1st stage F-value	-	-	-	-	19.39	24.68
Hansen-J	-	-	-	-	15.6	13.7
(p-value)	-	-	-	-	(.161)	(.251)
# observations	106	106	106	106	93	93
R ²	.252	.252	-	-	.228	.178

♠ reimbursement share in percent, 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 3: Trust and Reimbursement: OLS, Fractional-Probit and IV- regression results

It turns out that higher levels of trust do not significantly affect (or are not significantly affected by) higher levels of compensation for research and development. This result is robust to a wide range of further alternative specifications.⁵⁵ Bearing the result

⁵⁵We carried our a long sequence of further robustness checks. Most importantly, the results do not

from the previous section in mind, this implies that the higher quality levels observed with increased trust are not accompanied by significantly higher reimbursement shares. Note that, as discussed above, information with regard to the reimbursement of costs and prices is highly sensitive, which may have introduced additional noise to this self-reported measure. In the following subsection, we mainly discuss the third hypothesis; but we also present additional results indicating that the overall compensation (including information rents) is decreasing in the level of trust observed.

5.3 Trust and Competition

Our third hypothesis is that higher levels of trust should be associated with more competition induced by the OEM. Intuitively, we might imagine that the supplier faces attempts at extracting its information rent by the OEM either through opportunistic behavior (destroying trust) or by inducing tougher competition at the investment stage, in which the blueprints are developed. If an OEM induces tough competition, but then plays by the rules, then tougher competition should be associated with higher levels of trust. This is the mechanism underlying our model. We can use the detail and structure of our questionnaire study to predict a specific pattern with regard to the relationship between trust and competition over the different stages of vehicle and part development:

1. In the pre-development stage the investments by the supplier are *not model-specific* and therefore the relationship-specific repeated game arguments of our model (in particular with regard to the supplier's incentive constraint) do not directly apply. As a result, our model provides no reasons to expect a significant positive relationship between trust and competition.
2. In the development stage, model- and relationship-specific investments are required from the supplier. This is the exact setting set out in our model and envisioned in Proposition 1. Therefore, we would expect trust and competition to be positively associated in this phase (Hypothesis 2).

change for estimation of the sample with all available responses to the compensation question. We carried out a large battery of further tests including: We constructed a dummy with compensation above the minimum as a dependent variable, we restricted the sample to observations with positive compensation, we excluded supplier revenues and OEM dummies from the regressions, we interacted the trust measures with the part-specific dummy variables. In none of these specifications was there a (positive or negative) significant relationship between trust and compensation.

3. In the series production stage, our model also predicts a positive association. A higher level of trust relaxes the supplier’s IC constraint, so that the OEM can attempt to reduce information rents. The supplier in practice realizes its information rents mainly through markups on the parts produced, given that it is awarded the production contract. Therefore, we would expect that with higher levels of trust, more competition can be induced in series production, as well (Hypothesis 2).

Notice that the existing relational contracts literature would generally tend to predict a negative relationship between arms-length contracting/competition and trust.

Our empirical test is therefore to analyze how supplier competition in the different stages of production — measured by the number of parallel suppliers involved in the pre-development, development and production of the specific model, respectively — are associated with our trust measure.⁵⁶ We report OLS results below.⁵⁷ In the following specification n_{ij} is the number of suppliers employed by customer (OEM) j for part i , κ a constant, x is the trust measure and Z the vector of control variables including the investment level/quality level of the part.

$$n_{ij} = \kappa + \beta * x_{ij} + \gamma * Z_i + \epsilon_{ij} \quad (8)$$

Higher levels of trust should be associated with a higher incentive to extract rents by means of more competition, that is employing more parallel suppliers. According to our second hypothesis, we would expect a positive sign for β in the specification for development and series production, but not for the pre-development phase. The results are found in Table ??.

With regard to our central hypothesis, we find that the trust measure is strongly, positively and significantly associated with the number of suppliers at the development and the series production stage. For development, an increase of trust (standard index) by one standard deviation is related to an expected additional .40 suppliers, for the normalized trust index, the increase per standard deviation is around .18. Note that this

⁵⁶We do not apply the instrumental variable at this level, since exogeneity with regard to the number of suppliers chosen is less clear.

⁵⁷Taking the structure of our data into account, since significant shares of the observations are at the lower limit of 1 supplier we also carried out Tobit regressions as well as Probit regressions for the occurrence of multiple sourcing. The results are qualitatively identical.

Variables	Pre-Dev. [♣]		Dev. [♣]		Ser. Prod. [♣]	
trust index	-.108 (.468)	- -	.318*** (.009)	- -	.167* (.056)	- -
trust index (n)	- -	-.147 (0.150)	- -	.181* (0.071)	- -	.165* (.077)
tech. Soph. (D)	.278 (.245)	.293 (.213)	-.308* (.065)	-.368** (.033)	-.405*** (.001)	-.432*** (.001)
size of part (D)	.071 (.758)	.071 (.749)	.353 (.208)	.356 (.208)	-.380*** (.001)	-.353*** (.001)
interaction	.029 (.932)	.020 (.952)	-.711* (.098)	-.716 (.112)	.249 (.148)	.227 (.198)
supplier revenues	-.002 (.667)	-.003 (.564)	.004*** (.001)	.004*** (.001)	.007 (.200)	.007 (.180)
const	2.578 (.001)	1.983 (.000)	-.587 (.387)	1.045 (.000)	.404 (.334)	1.317 (.000)
OEM-FE	yes	yes	yes	yes	yes	yes
# observations	82	82	126	126	127	127
R ²	.226	.238	.266	.241	.226	.249

[♣] coefficients and (p-values) reported; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Trust and Competition: OLS-regression results

must be viewed in relation to the average number of suppliers at this stage, which is 1.54. In series production, we also find a positive relationship between trust and competition, though the coefficients are smaller than in the development stage. An increase of trust (standard index) by one standard deviation is associated with an increase in the number of suppliers by .20, while for the normalized index an increase by one standard deviation increases the number of suppliers by .16.⁵⁸ Again, it is important to note the average number of suppliers employed at this stage in relation, which is lower at 1.22. For the more basic, non relationship-specific research during pre-development, we do not find a significant coefficient of trust on competition.

Considering the results in the other stages sheds further light on the issue and corroborates our characterization of the different phases. Noticeably, for the pre-development phase, our standard controls, in particular the size and sophistication of the part, do not play a significant role. This reflects the observation that the non-model-specific fundamental research involved at this stage follows a different set of rules. It is often initiated purely by the upstream suppliers, and when it is not, the greater uncertainty involved

⁵⁸As one would expect from an economies of scale rationale, in production the size and complexity of products is associated with fewer employed suppliers, as they will tend to be more costly.

in the project gives an additional incentive to involve more firms.

5.4 Further Robustness Checks: SEM and Correlations

We have shown that, individually, both part quality and the number of suppliers are positively associated with the level of trust observed in a supplier-buyer relationship, while there is no significant concurrent increase in compensation to the supplier. We carry out two further final robustness exercises. First, we run a simultaneous equation model, in which we allow for correlation of the error terms between each equation. The results (despite the lower number of observations) are qualitatively completely in line with what we observe in the previous subsections, see the table ?? in the Appendix. Finally, we run regressions for the occurrence of quality problems as well as for the number of suppliers in development while “controlling” for the respective other variable, in the spirit of directly testing Proposition 1. The structure of correlations remains as predicted by our model, see tables ?? and ?? in the Appendix.

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, we are able to shed light on the role of trust as fostered or squandered in pairwise economic relationships, both with a theoretical analysis and a consistent empirical investigation.

Our simple theory shows that higher levels of trust lead to higher relationship-specific investments and, more surprisingly, that an increase in suppliers’ trust is associated with more competition in the procurement process because trust and the quasi-rents from limited competition are substitutes in terms of sustaining cooperative behavior (investment and connected reward) between buyers and seller.

We are then able to document empirically how an OEM’s investment in supplier trust, characterized by the OEM decision to forgo (often short-term) opportunities of appropriating 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 callbacks on the parts supplied and final vehicles.

In line with our surprising theoretical result, we also show that higher levels of trust by suppliers are associated with the downstream procurer's decision to have a larger number of upstream suppliers compete for the development, or the production contract. We consider this result surprising especially in view of the fact that our measure of "trust" is not based on just one individual response, but instead composed of the responses of different people in the same firm, that focus on different factors when asserting their level of trust in the other party. Indeed, some of our measures are more closely related to the respect for intellectual property rights, other measures are associated with fair compensation as opposed to frequent price renegotiations.

One might finally be tempted to ask for competing explanations of the observed facts. In particular, the pre-selection of a smaller number from the subtotal of potential suppliers may involve quality considerations, together with the fact that there is a positive cost involving procurement from an additional supplier. While both considerations undoubtedly may exercise force, they are tangential only to our main points, in which we relate our trust measure to investment and competition. Indeed, we do do simultaneously account for a number of effects within a structure for which we could not find a competing alternative.

Theoretical Appendix

Proof of Proposition 1.

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

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

We have

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

with a slight abuse of notation we obtain

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

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

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

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

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

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:

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

which can be written as:

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

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

Proof of Proposition 2.

Notice first that equation (??) implies that if δ increases either n^* or I^* have to increase.

Consider next the overall effect of δ on both endogenous variables n^* and I^* . We proceed in steps and start from the effect of δ on the optimal number of suppliers n^* .

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

$$\left[v(I_n) - \frac{nI_n}{\delta} - \theta^{e'}(n) \right] \frac{1}{1-\delta} \geq \left[v(I_{\tilde{n}}) - \frac{\tilde{n}I_{\tilde{n}}}{\delta} - \theta^{e'}(\tilde{n}) \right] \frac{1}{1-\delta}$$

or equivalently

$$\theta^{e'}(\tilde{n}) - \theta^{e'}(n) \geq \left[v(I_{\tilde{n}}) - \frac{\tilde{n}I_{\tilde{n}}}{\delta} \right] - \left[v(I_n) - \frac{nI_n}{\delta} \right]$$

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

$$\frac{d}{d\delta} \left\{ \left[v(I_{\tilde{n}}) - \frac{\tilde{n}I_{\tilde{n}}}{\delta} \right] - \left[v(I_n) - \frac{nI_n}{\delta} \right] \right\} = \frac{1}{\delta} [v'(I_{\tilde{n}})I_{\tilde{n}} - v'(I_n)I_n]$$

and with a Taylor approximation

$$v'(I_{\tilde{n}})I_{\tilde{n}} - v'(I_n)I_n = [v''(\zeta)\zeta + v'(\zeta)](I_{\tilde{n}} - I_n) = \left[\frac{v''(\zeta)}{v'(\zeta)}\zeta + 1 \right] \frac{(I_{\tilde{n}} - I_n)}{v'(\zeta)}$$

so that, finally,

$$\text{sgn} \left\{ \frac{d}{d\delta} \left\{ \left[v(I_{\tilde{n}}) - \frac{\tilde{n}I_{\tilde{n}}}{\delta} \right] - \left[v(I_n) - \frac{nI_n}{\delta} \right] \right\} \right\} = \text{sgn} \left\{ \left[\frac{v''(\zeta)}{v'(\zeta)}\zeta + 1 \right] \right\}. \quad (10)$$

Clearly if $v''(\cdot)$ is sufficiently negative the sign r.h.s. of (??) is negative which proves our claim.

Consider now the effect of δ on the optimal investment \underline{I}^* . If n^* were a continuous variable than equation (??) above, immediately implies 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 (??) 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 (??) is smaller when n^* increases than when it remains constant.

7 Empirical Appendix: Descriptive Statistics and Selected Robustness Checks

	trust ind.	trust ind. (n)	failure pr.	compensation	# suppl. dev
trust index (n)	0.7740***				
(p-level, obs)	(.000, 343)				
failure prob.	-.0313	-.0376			
(p-level, obs)	(.673, 184)	(.613, 184)			
compensation	.0007	.0131	.0695		
(p-level, obs)	(.916, 225)	(.845, 225)	(.425, 134)		
# suppliers dev	.0414	.0568	-.0808	-.1595*	
(p-level, obs)	(.536, 225)	(.396, 225)	(.324, 151)	(.055, 145)	
instrument	-.3525***	-.3249***	.0640	.0935	-.0383
(p-level, obs)	(.000, 280)	(.000, 279)	(.417, 163)	(.191, 197)	(.604, 185)

Table 5: Pairwise correlations of the main variables of interest

Variable	Mean (Std. Dev.)	Min	Max	Obs.
When is supplier asked to participate?	2.77 (1.37)	1	6	144
How often is progress coordinated?	2.98 (.57)	1	5	151
Share of efforts absorbed by supplier	3.50 (1.33)	1	5	142
Cost reimbursement if subsequent contract	2.31 (1.52)	1	5	246
Cost reimbursement if no subsequent contract	2.39 (1.59)	1	5	232
Specificity development objectives wrt...				
... content	2.33 (.97)	1	5	350
... time-frame	1.85 (.96)	1	5	350
... financial engagement	2.22 (1.14)	1	5	343
OEM's supplier choice criteria:				
... importance of supplier price	5.10 (1.16)	1	6	158
... importance of duration cooperation	4.70 (.99)	1	6	160
... importance of trust	4.89 (.98)	1	6	159

Table 6: Relationship Characteristics: **Pre-Development** (Suppliers' view)

Variable	Mean (Std. Dev.)	Min	Max	Obs.
How specific and detailed are specifications?	2.39 (1.02)	1	5	231
Supplier's degree of freedom	2.91 (.86)	1	5	231
Desired degree of freedom	3.62 (.77)	1	5	229
OEM's contribution to development	2.37 (1.10)	1	5	200
Frequency of IPR conflicts	2.24 (.87)	1	5	194
OEM's supplier choice criteria:				
... importance of supplier price	5.37 (.72)	2.5	6	387
... importance of duration cooperation	4.52 (1.00)	1	6	387
... importance of personal contact	4.52 (.98)	1	6	387
... importance of certification	4.39 (1.14)	1	6	377
... importance of trust	4.90 (.93)	1	6	384

Table 7: Relationship Characteristics: **Development** (Suppliers' view)

Variable	Mean (Std. Dev.)	Min	Max	Obs.
How often does OEM produce part himself?	1.69 (1.31)	1	6	210
OEM's supplier choice criteria:				
... importance of supplier price	5.70 (.52)	3	6	253
... importance of duration cooperation	4.38 (1.07)	1	6	253
... importance of personal contact	4.44 (1.10)	1	6	253
... importance of certification	4.28 (1.19)	1	6	250
... importance of trust	4.73 (.98)	1	6	252

Table 8: Relationship Characteristics: **Series Production** (Suppliers' view)

Variable	Mean (Std. Dev.)	Min	Max	Obs.
Number of competing suppliers	2.29 (.92)	1	5	144
Frequency of subsequent development projects	3.23 (1.11)	1	5	322
How often were projects discontinued in last 5 yrs.	2.00 (.88)	1	5	139
How often were the following employed...				
... preselection of a specific supplier	4.43 (1.26)	1	6	351
... procurement among a ltd. number of suppliers	3.95 (1.44)	1	6	338

Table 9: Procurement Decisions: **Pre-Development** (Suppliers' view)

Variable	Mean (Std. Dev.)	Min	Max	Obs.
Frequency joint procurement dev. and production	3.76 (1.24)	1	5	363
Number of suppliers employed during...				
... product planning	2.32 (1.13)	1	5	167
... product specification	2.03 (1.02)	1	5	177
... concept development	2.12 (1.07)	1	5	208
... detailed development	1.51 (0.90)	1	5	210
How often were the following employed...				
... preselection of a specific supplier	3.06 (1.52)	1	6	259
... procurement among a ltd. number of suppliers	5.18 (1.10)	1	6	264
... open procurement	1.97 (1.41)	1	6	255

Table 10: Procurement Decisions: **Development** (Suppliers' view)

Variable	Mean (Std. Dev.)	Min	Max	Obs.
Number of suppliers employed...				
... at production start	1.22 (.63)	1	5	251
... after 1-2 years	1.47 (.78)	1	5	249
... after more than 2 years	1.59 (.81)	1	5	246
How often were the following employed...				
... preselection of a specific supplier	2.98 (1.63)	1	6	248
... procurement among a ltd. number of suppliers	4.55 (1.52)	1	6	248
... open procurement	2.44 (1.66)	1	6	243

Table 11: Procurement Decisions: **Series Production** (Suppliers' view)

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)
Cov(e.quality_perc,e.compensation_perc)				
	.003	(.523)	.003	(.504)
cov(e.quality_perc,e.suppliersDEV)				
	-.016	(.186)	-.018	(.178)
: cov(e.compensation_perc,e.suppliersDEV)				
	-.030	(.248)	-.032	(.213)

Customer fixed effects included, 84 observations, coefficients and (p-values) reported, dependent variables: likelihood of quality issues (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 12: Estimation results : Simultaneous equation models

Variable	Coefficient	(p-value)	Coefficient	(p-value)
trust index	-.184	(.077)	-	-
trust index (n)	-	-	-.100	(.107)
# sup. dev.	-.024	(.064)	-.047	(.460)
tech. soph. (D)	.020	(.174)	.052	(.765)
size of part (D)	.682	(.169)	.686	(.000)
interaction	-.069	(.295)	0.095	(.744)
supplier revenues	-.005	(.007)	-.005	(.478)
const	-.175	(.421)	-1.091	(.000)
OEM-FE	yes	-	yes	-
# obs	126	-	126	-

Table 13: Robustness Check: Fractional probit results for probability of quality issues arising; with # of suppliers as a control

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)
OEM-FE	yes	-	yes	-
# obs	126	-	126	-
R ²	.266	-	.243	-

Table 14: Robustness Check: OLS results for # of suppliers; with probability of quality issues arising as a control