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The Organization of Vertical Relationships

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By

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I hereby declare that the work presented in this thesis is my own.

Bart S. Vanneste

ABSTRACT

The Organization of Vertical Relationships

Bart S. Vanneste

In this dissertation I address the question of how vertical relationships, i.e. relationships between subsequent stages of a supply chain, are different within than between firms. While prior research has explored extensively the choice between organizing within versus between firms, we know little about how these alternatives are different. In this dissertation I use three settings in which I directly and simultaneously observe elements of vertical relationships both within and between firms.

In the first study, I use interview data from respondents in eight multi-business unit companies on similar internal and external vertical relationships. I find that cooperation is often higher between than within firms, because it is harder to fire internal than external units. I provide a formal model through which I show the generalizability of my findings and generate some empirical predictions.

In the second study, I use survey data on internal and external supplier relationships in the US automobile industry. I study how stronger incentives between than within firms influence the attribution of trustworthiness to exchange partners. Because cooperation may arise from trustworthiness or incentives, the presence of strong incentives hampers the attribution of trustworthiness and development of trust. In line with this argument, I find that trust between exchange partners increases more with relationship duration and employee co-location under vertical integration than non-integration.

In the third study, my empirical setting is a Dutch production facility of a company active in the raw materials industry. I compare their written agreements for maintenance services with internal and external suppliers. Controlling for transaction and market characteristics. I find that external agreements contain more incentive clauses and that they have a similar number of pages for describing the (coordination of the) service.

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CHAPTER 1

Introduction

1.1. Background

A vertical relationship is a relationship between two subsequent stages of a value chain. A value chain is the collection of activities necessary to transform basic inputs into a final product or service (Porter, 1985). In the most elementary form, an upstream stage provides an (intermediate) service or product to a downstream stage for a (monetary) reward. Examples of vertical relationships are a car parts producer and a car assembler, a wind turbine manufacturer and an electricity producer, and a chemical components supplier and a drug manufacturer. A closely related concept is a horizontal relationship, which is a relationship between two similar stages of a value chain. Many relationships between airlines fall under this category, such as British Airways and the oneworld alliance (with among others American Airlines and Cathay Pacific). While many of the ideas developed in this dissertation also apply to horizontal relationships, the focus is on vertical relationships.

A vertical relationship can take place within a firm or between firms. If two subsequent steps of a value chain are organized within a single firm, this is referred to as vertical integration. Alternatively, activities can be allocated to different firms, which is called non-integration (Williamson, 1985; Grossman and Hart, 1986). Interestingly, all three examples of vertical relationships above are found under vertical integration and non-integration. First, as I will discuss in chapter 3, the auto assemblers Ford and Chrysler source some of their key parts from external suppliers and some from divisions that belong to the same company. Second, Spanish company Acciona generates energy with wind turbines that it has developed and manufactured internally. Siemens is a big rival in the production of wind turbines. However, Siemens is not active in the downstream stage and only sell to companies active in the energy generation market. Third, for the production of its drugs Merck needs a variety of basic chemical components. Merck sources some of these from external suppliers and it produces others internally.

The decision to vertically integrate - what should be done inside the firm and what should be done outside the firm - is one of the most strategic corporate decisions. Grant (2002) uses three criteria to characterize strategic decisions: important, significant commitment of resources, and difficult to reverse. All of these apply to the vertical integration decision. First, setting the boundary of the firm is important because it influences the development of a firm's competitive advantage. Competitive advantage often arises from those resources and capabilities that accumulate over time rather than from those that are readily bought (Dierickx and Cool, 1989). As such, the vertical integration decision strongly determines in which areas a company can develop a competitive advantage and in which areas not. Current competitive advantage is an important factor in the decision to outsource or insource and this decision in turn strongly impacts future competitive advantage. Second, changing the boundary of the firm involves a significant commitment of resources because processes need to be integrated or separated. This could involve changes to work flows, adjustments to equipment, and additional training for employees. Furthermore, even aside from implementation, performing an additional step in the value chain in-house requires significant resources. Third, precisely because (dis-)integration costs can be substantial and because resources and capabilities change over time, boundary decisions are hard to reverse.

Because of their strategic relevance, firm boundary decisions have received a lot of theoretical attention (Coase, 1937; Alchian and Demsetz, 1972; Williamson, 1975; Grossman and Hart, 1986). This literature is often referred to as theories of the firm. While several such theories exist, each with its own focus, the consensus is that economic activity inside a firm boundary is differently organized than economic activity across such boundary in some fundamental respect. Because of this difference, it is suggested that some relationships are more efficiently organized in hierarchies (i.e. within a firm) and others through markets (i.e. between firms). While researchers have repeatedly studied the allocation of economic activity to either firms or markets (see for reviews David and Han, 2004; Geyskens et al., 2006), few have directly studied the actual differences between firms and markets on which these theories critically depend.

Some qualitative evidence suggests however that the distinction between markets and hierarchies is less clear cut than theory suggests. In particular, "market" mechanisms are used in firms and hierarchical mechanisms in markets. For example, contracts between firms contain command structures and dispute resolution procedures that mirror authority relations typically ascribed to firms (Stinchcombe, 1985). Furthermore, business men and women of different firms often rely on trust rather than contracts to resolve problems, just as they would inside a single firm (Macaulay, 1963). Likewise, transfer pricing between profit centers of multidivisional organizations bring "market" mechanisms inside firms (Eccles, 1985). These empirical realities suggest that the impact of firm boundaries may be less than currently assumed (Powell, 1987; Hennart, 1993). Furthermore, it reminds us that when using the terminology of "firms" and "markets", it is easy to forget that behind "the façade of the market" simply lies another firm (Jacobides and Winter, 2005, p. 398).

While the studies above greatly enhance our understanding of the organization of economic activity, they cannot inform us about any comparative difference between external and internal vertical relationships because they study only one type at a time. A few studies directly compare internal and external transactions and provide interesting evidence on the impact of firm boundaries, but they still leave open many questions because they primarily rely on qualitative evidence (Bradach, 1997), or ignore the selection into firms or markets and thus do not ensure comparability of the internal and external relationships (Walker and Poppo, 1991; Poppo, 1995).

1.2. Research Question

In this dissertation I address the central question: how are relationships between subsequent stages of a supply chain managed differently within than between firms? I shift the focus away from where relationships are managed (within versus between firms)

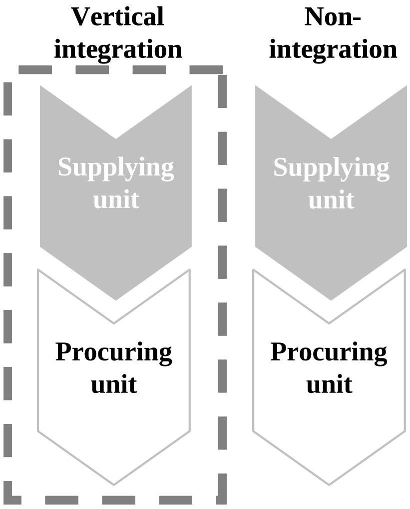

Figure 1.1. Research question

to the differences between such relationships. Figure 1.1 gives a graphical representation of the main components of the research question. The unit of analysis is the relationship between an upstream and a downstream unit, or equivalently between a supplying and a procuring unit. The main treatment is integration versus non-integration.

Studying the differences between internal and external relationships is important for the following reasons. First, it will give us a better understanding of what firm boundaries do. This topic is central to many theories of the firm, yet lacks empirical evidence. If firm boundary decisions are important (and the amount of research on this topic suggest they are), then understanding what these choices are about is essential. Second, a greater understanding should help us build more prescriptively valid theories. While more accurate assumptions do not necessarily lead to better predictions, a greater understanding could reveal some important boundary conditions to the theories. Third, a deeper understanding should increase the descriptive validity of the theories. Such understanding is essential if theories are used to make normative statements (on the dangers of promoting "invalid" theories, see Ghoshal and Moran, 1996).

1.3. Literature Review

In this section I provide a review of the most relevant literature on the organization of economic activity. This literature is referred to as the theory of the firm. A theory of the firm must address two questions (Holmström and Tirole, 1989). First, why do firms exist? Second, what determines their boundaries? While many references are made to the theory of the firm, many theories of the firm exist. In this section I give short summary statements of the two most influential theories of the firm (Gibbons, 2005). In particular, I will focus on transaction cost economics (Coase, 1937; Williamson, 1975, 1985) and property rights theory (Grossman and Hart, 1986; Hart and Moore, 1990).[1] In this section I focus on the core arguments of each theory, whereby the goal is to understand in each theory what the differences are between governance modes and to a lesser extent the selection into those governance modes.

1.3.1. Transaction Cost Economics

The roots of transaction cost economics (TCE) trace back to the seminal inquiry by Coase (1937) into the reasons of firm existence. One of Coase's key insights was that there are costs to using the market for conducting economic exchanges, as there are costs for organizing exchanges within a firm. Building on these ideas, Williamson (1975, 1985) developed a branch of theory which has come to be known as TCE. Few theories are as influential as Williamson's work, which has found applications in many disciplines such as finance, strategy, marketing, economics, and law.

The main research question of TCE is how economic activity can be most efficiently organized. The unit of analysis is the transaction, which occurs "when a good or service is transferred across a technologically separable interface" (Williamson, 1985, p. 1). The core argument can be succinctly summarized in the discriminating alignment hypothesis: "transactions, which differ in their attributes, are aligned with governance structures, which differ in their costs and competencies, in a discriminating (mainly, transaction-cost-economizing) way" (Williamson, 1991, p. 277). Thus, TCE predicts that governance structures are matched to transactions in an efficient way.

[1] For other theories of the firm in economics see Gibbons (2005) and in organization theory see Santos and Eisenhardt (2005).

TCE distinguishes between two main alternative governance modes: markets and hierarchies (Coase, 1937; Williamson, 1975). Markets are governed by a price mechanism. Prices provide sufficient information about supply and demand to direct resources (Hayek, 1945). The dependence between transacting parties is low. Buyers can change to alternative suppliers with little cost and vice-versa. In the event of conflict, parties will take their business somewhere else. Hierarchies are governed by authority. Employees are directed under single ownership. Because employees are not residual claimants, they have less incentive to create conflict. Should conflict occur, authority will step in to resolve it rather than external courts. Williamson (1991) introduced a third governance mode, hybrids, as an intermediate option between markets and hierarchies. Hybrids are typically governed by long term contracts. While transacting parties are still legally independent, hybrids are characterized by bilateral dependence. Switching involves substantial costs. Because of this, parties first attempt to resolve any conflict within the relationship.

For a given transaction, the optimal governance mode is the one with the lowest total cost. TCE distinguishes between production costs – the costs of making a product or service – and transaction costs – the costs of conducting an exchange. TCE focuses on the latter, while implicitly assuming that production costs are the same when making or buying. This assumption has not gone unchallenged (Demsetz, 1988; Jacobides and Hitt, 2005), and as Jacobides (2005) points out for some transactions buying may not be an option.

The costs of conducting an exchange are usually divided into ex-ante and ex-post transaction costs. Ex-ante costs are "the costs of drafting, negotiating, and safeguarding an agreement"(Williamson, 1985, p. 20). These include the resources spent on negotiating and lawyers fees. Ex-post costs include maladaptation costs, bargaining costs, and monitoring costs (Williamson, 1985; Dahlstrom and Nygaard, 1999). Maladaptation occurs if a governance structure fails to adjust to changing circumstances. Bargaining costs include haggling to realign the terms of trade over time (Buvik and

John, 2000). Monitoring costs are the expenditures to guarantee fulfillment of contractual obligations (Dahlstrom and Nygaard, 1999).

A further distinction can be made between external and internal transaction costs, sometimes referred to as market costs and organization costs (Coase, 1937). While efforts have been mostly directed at understanding what affects market costs and less at uncovering the drivers of organization costs, theoretical predictions of governance choice depend on a comparative assessment of both. In general, the marvel of the market is that it provides high-powered incentives which allow opportunistic actors to ruthlessly pursue their self-interests. At the same time these interests may be conflicting, making it necessary to implement costly safeguards. On the other hand, the problem of opportunism is much less severe in firms. Williamson (1975) specifies three reasons. First, employees are not fully rewarded on firms' profit, lessening the incentives to behave opportunistically. At the same time, a firm can punish non-cooperation through multiple means, for example by withholding promotion. Second, internal auditors have access to information that outside auditors have not. This makes opportunism inside the firm more easily detectable and therefore less likely. Third, conflicts that do arise can be much more effectively addressed through fiat, whereas markets often have to rely on costlier legal courts.

Transaction costs vary with transaction characteristics, but do so differently for each governance mode. Where do these costs come from? Fundamentally, these costs arise because of bounded rationality and opportunism. Bounded rationality implies that people are "intendedly rational, but only limited so"(Simon, 1957, p. xxiv). Opportunism is "self-interest seeking with guile" (Williamson, 1975, p. 255) and implies that people may engage in such behaviors as "lying, stealing, cheating, and calculated efforts to mislead, distort, disguise, obfuscate, or otherwise confuse" (Williamson, 1985, p. 47).

Because of the combination of these characteristics two fundamental problems arise: hold-up and adaptation (Gibbons, 2005). Hold-up is possible whenever an exchange partner makes relationship specific investments (Klein et al., 1978). Per definition, these investments are worth less in their second-best use than in the focal relationship. An opportunistic counterparty will try to appropriate as much of the resulting quasi-rents as possible, where quasi-rents is the difference in values between the first and second-best use of the investment. For example, once a supplier has made a specific investment, the investment costs are sunk and the buyer could force the supplier to exchange under less favorable conditions than the supplier had anticipated. If the supplier had anticipated the hold-up correctly, the supplier might not have made the specific investment, nor entered into the transaction. However, given that the investment is made, it is more profitable for the supplier to stay in the relationship than to exit.

Related to the hold-up problem is the adaptation problem, which is concerned with "adaptive, sequential decision-making" in uncertain environments (Williamson, 1975, p. 40). Changing circumstances may require coordinated action of exchange partners (Williamson, 1991). Opportunistic partners may attempt to exploit these changing circumstances to their benefit.

Governance mechanisms differ in their adaptive capacity and their ability to prevent hold-up problems. Because of better incentive alignment, hierarchies are more effective in mitigating the effects of opportunism than hybrids, which in turn are more effective than market relationships (Williamson, 1991). However, these protection mechanisms come at a cost. In general, the more hierarchical the costlier they become. As such, these protection mechanisms are only warranted if the potential for hold-up and adaptation problems is substantial.

What drives the potential for hold-up and adaptation problems? Williamson (1985) identifies three such factors: asset specificity, frequency, and uncertainty. Because asset specificity has received the most theoretical and empirical attention, I will only illustrate this aspect. Asset specificity is the degree to which an asset loses its value in the next best alternative use (Klein et al., 1978). As asset specificity increases, the potential for hold-up goes up as described above. Furthermore, with asset specificity comes bilateral dependence (Williamson, 1991). In the event of disturbances, unilateral adjustments are usually not sufficient and coordinated action is required. However, given different incentives, each party may favor a different type of adaptation.

The number of empirical papers that test TCE predictions run into the hundreds. The typical study correlates drivers of hold-up or adaptation problems, such as asset specificity, with governance structure. Based on a meta-analysis of 200 studies, Geyskens et al. (2006) conclude that the empirical evidence provides strong support for governance mode decisions consistent with TCE reasoning.

1.3.2. Property Rights Theory

Property rights theory (PRT) is developed as a direct response to TCE. One of the critiques of TCE is that it does not make explicit how transaction costs inside a firm depend on transaction characteristics (Grossman and Hart, 1986). This is problematic because TCE is concerned with a comparative assessment of governance modes. For example, given the premise that asset specificity drives up transaction costs in the market, one cannot claim that integration is preferred without knowing how asset specificity affects transaction costs inside the firm. PRT explicitly includes the costs and benefits of integration.

The main research question of PRT is how asset ownership can be most efficiently allocated. As in TCE, incomplete contracting and quasi-rents play an essential role. PRT distinguishes between two types of contractual rights: specific rights and residual right (Grossman and Hart, 1986; Hart and Moore, 1990). Specific rights spell out the responsibilities and action to be taken in specific events. Whenever it is too costly to list all specific rights, it may be optimal for one party to purchase the residual rights. Residual rights are the rights to make decision in all events not specified in the contract. Ownership is the purchase of these residual rights. A firm is defined by the assets it owns or has control over. Integration thus changes who has the residual rights of an asset (Grossman and Hart, 1986).

While TCE focuses on ex-post haggling costs and takes the relationship specific assets as given, PRT assumes efficient ex-post bargaining and focuses on the incentives to make those specific investments (Grossman and Hart, 1986; Hart and Moore, 1990). In PRT efficient bargaining allows parties to share the surplus from their (non-contractible) specific investments. Because the returns from their investments are shared, the parties' incentives to invest may not be fully aligned. Because ownership determines who has the right to make non-contractible investments, ownership determines the creation of surplus. In effect, ownership rights allow one party to make the investment decisions for both assets. By assumption, this party will still make those decisions in a way that maximizes individual payoffs, rather than joint payoffs. Thus, regardless of which party has ownership, ownership inevitably introduces distortions. The costs of integration are incentive distortion. Yet, these distortions are not equal and PRT predicts that the ownership structure will be chosen such that these distortions are minimized. Given certain separability assumptions, "[I]ntegration is therefore optimal when one firm's investment decision is particularly important relative to the other firm's, whereas non-integration is desirable when investment decisions are "somewhat" important." (Grossman and Hart, 1986, p. 716-717).

Thus, PRT is concerned with the creation of surplus (i.e., quasi-rents), while TCE focuses on the division of surplus (e.g., hold-up). In PRT the division of surplus is assumed not to be problematic and occurs through costless bargaining. In TCE the creation of surplus occurs through the investments in asset specificity, the level of which is usually taken as exogenous.

Under PRT, the differences between integration and non-integration are restricted to residual rights. While exchange partners are as self-interested within as between firms, ownership or residual rights must be allocated efficiently to bring investment decisions in line with joint maximization. Unlike TCE, PRT does not assume that integration makes auditing cheaper or more effective (Grossman and Hart, 1986). Furthermore, the costs of writing contractual provisions are assumed to be equal under integration and non-integration (Grossman and Hart, 1986).

The empirical tests of PRT are few (see for an example Novak and Eppinger, 2001). Possibly, this is because PRT is mostly a formal theory. Empirical testing would require the measurement of marginal effects of investments on alternative payoffs, which are by definition not observed in practice and also hard to infer (Whinston, 2003). Also, reinterpretation of empirical TCE studies using a PRT lens is often not feasible because the theories rely on related but different constructs (Whinston, 2003).

Because the empirical work in PRT is limited and empirical TCE research almost exclusively focuses on the boundary decision, Gibbons (2005) remarked that theories of the firm may at the moment be called more appropriately theories of the boundaries of the firm.

1.3.3. Vertical and Authority Relationships

A vertical relationship can have two different meanings. The first is as described above: a relationship between two subsequent stages of a value chain. This relationship is a flow of products, services, or activities. The second meaning refers to an authority relationship between people, for example between a boss and an employee. This relationship represents a flow of instructions, commands, feedback, advice, or decisions. Authority indicates a residual right, i.e. the right to decide in situations not specified under a contract. In TCE this authority originates in the employment contract (Simon, 1951; Williamson, 1975). In PRT this authority arises from asset ownership (Grossman and Hart, 1986).

The two meanings are different. In fact, the two are logically independent. Take for example a value chain with two stages, in which person A runs the first stage and person B the second. For this single value chain, four different authority structures are possible. First, A is the boss of B. Second, B is the boss of A. Third, A and B are not subordinates of each other, but share a common boss. Fourth, A and B are not subordinates of each other and do not share a common boss. In this dissertation I will refer to adjacent steps in a value chain as a vertical relationship and to a reporting relationship as an authority relationship.

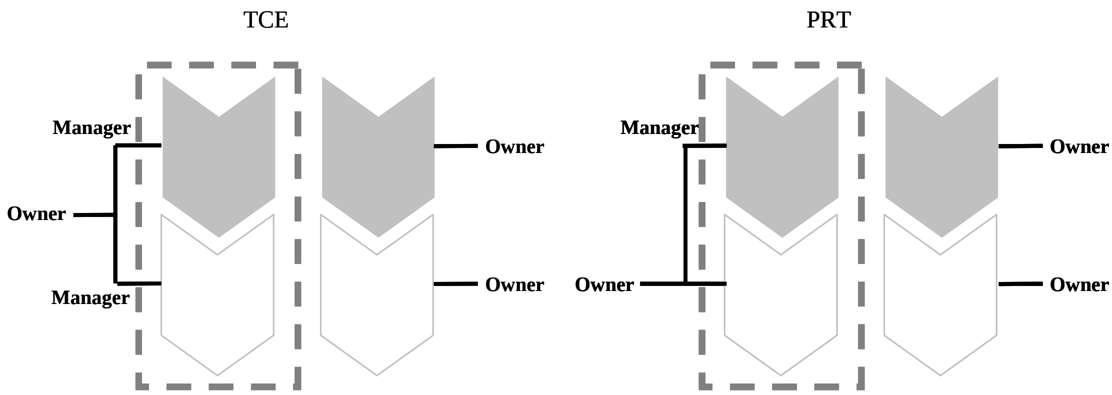

Figure 1.2. Authority relationships in transaction cost economics and property rights theory under integration and non-integration

TCE and PRT have the same authority relationships under non-integration, but these theories assume different authority relationships under integration. Figure 1.2 gives a graphical representation of the authority relationships in TCE and PRT under integration and non-integration. Under non-integration, the two steps of the value chain belong to different firms. As such the people who run the different steps of the value chain do not have an authority relationship with each other, nor do they share a common boss. In Figure 1.2 each step is owned by a different owner under non-integration (for both TCE and PRT).

Under integration, PRT assumes that one of the parties of the value chain has an authority relationship over the other. For example, in Figure 1.2 the upstream party is a subordinate of the downstream party. I refer in the Figure to one as owner and to the other as manager. I also could have labelled them employee and boss. The distinction is not important for the argument. The alternative example is that downstream is a subordinate of upstream (not shown here). Regardless of which party is a subordinate of whom, the key point is that the parties are always linked through an authority relationship. They cannot be both subordinates of the same boss. In PRT it would be difficult to represent a vertical relationship between two business unit managers of a large corporation, if the business unit managers are not subordinates of each other but of a common boss. This led Hart and Holmström (2008) to remark that PRT is more applicable to owner-managed than large companies.

Under integration, TCE assumes that both stages of the value chain fall under a common boss (Williamson, 1975). It is precisely because of a common boss that it argued that firms have advantages over markets, such as more efficient dispute resolution procedures. In Figure 1.2 the managers of the different value chain steps report to the same boss. The boss is referred to as owner. Again, the distinction is not important for the argument here.[2] Vertical integration is equated with forming a hierarchy of employee relationships. The managers of the two different stages are not subordinates of each other. They do not have control over each other based on their hierarchical position. This is an important difference with PRT, in which it is assumed that one party always has control over the other.

If we take into account that behind "the façade of the market" simply lies another firm (Jacobides and Winter, 2005, p. 398), then what should "market" relationships look like according to TCE? Non-integration is simply a relationship between two different firms. Because they belong to different firms, each stage of the value chain has a different owner. Because they belong to firms, each stage of the value chain is managed by non-owners (i.e. employees) if we follow the assumptions of Williamson (1975). This last statement is more likely to hold for firms with more than a few employees. The consequence is that authority relationships are present in "market" relationships, as illustrated in Figure 1.3. While the authority relationships do not cross firm boundaries, an interesting implication emerges. Just as within firms, vertical relationships between firms are often managed by non-owners. If managers run steps in the value chain under integration, then likewise managers will be responsible for these steps under non-integration.

If this is the case, then the argument of Williamson (1975) that integration lowers the tendency of opportunistic behavior relative to non-integration because employees cannot keep most of the gains of such behavior does not follow. The incentives to behave opportunistically may not be very different for employees under non-integration, if they

[2] For other arguments the distinction between an owner and a boss matters greatly. For example, this distinction underlies much of prinicipal-agency theory on the consequences of separation of ownership and control (see for example Jensen and Meckling, 1976).

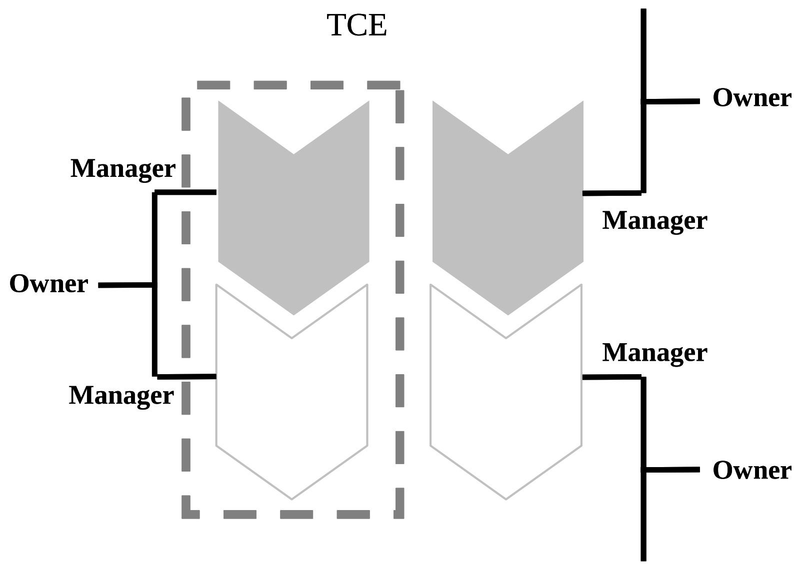

Figure 1.3. Authority relationships in hierarchies and “markets”

cannot keep most of the gains. The point here is not that incentives under integration and non-integration must be the same. Rather this suggests that the degree to which employees or managers can gain from opportunistic behavior - both under integration and non-integration - is variable and needs further clarification.

1.3.4. Conclusions from literature review

A number of conclusions from this literature review follow. First, a key consequence of integration relative to non-integration is a change in incentives. In TCE the trade-off is between incentive alignment under integration versus incentive intensity under non-integration. In PRT integration affects the incentives that exchange partners have to invest. Incentives also play a big role in other contributions to the theory of the firm (e.g. Alchian and Demsetz, 1972; Holmström and Milgrom, 1991; Holmström, 1999). Second, the role of organizational structure is underdeveloped in TCE and PRT. Currently, PRT cannot facilitate organizational structures that are more complex than one unit. While the role of organizational structure within firms is the main thrust behind empirical predictions of TCE, these insights are not sufficiently applied to organizational structures in relationships between firms. Third, because internal and external employees may be compensated in similar ways, the extent to which incentives are better aligned under integration versus non-integration is not clear.

1.4. Structure of Dissertation

Because of the theoretical importance of incentives in theories of the firm, and because of the limited comparative evidence on vertical relationships, I will focus in this dissertation on incentives and how they operate in vertical relationships within versus between firms. I have managed to find three settings in which I can directly and simultaneously observe elements of the management of relationships both within and between firms. I use different methods for each study: interviews and a formal model for the first, a survey for the second, and archival data for the third. Below I give a brief preview of each study (see Figure 1.4 for an overview of the structure of the dissertation).

In chapter 2, I explore the extent to which incentive alignment differs within versus between firms. In particular, I focus on how a joint future between exchange partners provides different incentives in internal than external relationships. My empirical setting for the first part of the chapter is plural sourcing relationships of eight multi-business unit companies in The Netherlands. In plural sourcing relationships a company makes (under integration) and buys (under non-integration) the same product. This ensures comparability of the transactions between the internal and external relationships. In the second part of the chapter, I provide a formal model through which I show the generalizability of my findings and generate some empirical predictions.

In chapter 3, I study how differences in incentive intensity between vertical integration and non-integration influence the attribution of trust to exchange partners. Because cooperation can arise from trust or incentives, it becomes harder to infer trustworthiness from cooperation when incentives are stronger. I test my arguments on survey data collected from assemblers in the US automobile industry. Because these auto assemblers produce some components in-house and source others from external

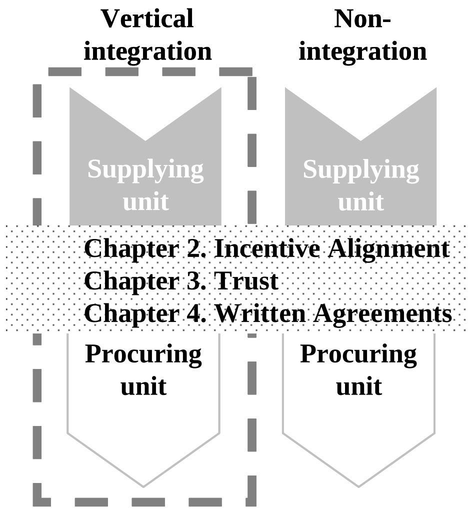

Figure 1.4. Structure of dissertation

suppliers, I am able to compare trust levels between internal and external vertical relationships.

In chapter 4, I analyze how written agreements are used within and between firms to provide incentives to exchange partners. My empirical setting is a Dutch production facility of a global company active in the raw materials industry. To maintain their production equipment they rely on internal and external suppliers and use written agreements for both. I have access to all written agreements between 2001 and 2007. I compare internal and external documents on a per clause basis.

In chapter 5, I provide conclusions.

CHAPTER 2

Vertical Integration and Incentive Alignment

2.1. Introduction

Theories of the firm have a unifying theme: firms provide incentive alignment when contracts in markets fail. Transaction cost economics argues that firms reduce haggling costs and facilitate adaptation relative to markets when contracts are incomplete (Williamson, 1975, 1985). The reason is that firms have weaker incentives, can monitor more effectively, and have authority structures to settle disputes. Team production theorists suggest that firms reduce shirking when production requires multiple and interdependent inputs whose contributions are difficult to measure separately (Alchian and Demsetz, 1972). The role of a firm's owner is to monitor production as efficiently as possible leading to less shirking relative to markets. As a reward the owner gets the residual value or the value that remains after production inputs are paid for. Property rights theory equates firm boundaries with asset ownership and maintains that such ownership aligns non-contractible investment decisions (Grossman and Hart, 1986; Hart and Moore, 1990). Incentive alignment arises from unified decision making, or the allocation of decision rights. Agency theorists propose that asset ownership can provide incentive alignment when agents face multiple tasks, some of which are uncontractible (Holmström and Milgrom, 1991; Holmström, 1999). Ownership influences who gets what, or determines the allocation of payoff rights. While the mechanisms vary across theories, the common prediction is that vertical integration is beneficial for incentive alignment on some dimension when contracts cannot be fully specified.

In qualitative fieldwork that I discuss in full in the next section, I find the exact opposite of what these theories assume: markets may provide stronger incentive alignment than firms even if contracts are incomplete. I compare vertical relationships that are integrated (i.e. within a firm) with those that are not integrated (i.e. between firms). To control for differences in transaction characteristics, I focus on settings of plural sourcing. Plural sourcing is defined as an instance where a firm makes and buys the same product (Puranam et al., 2006). Under plural sourcing, the goods and services exchanged in integrated and non-integrated vertical relationships are the same. This setting facilitates the direct comparison of incentive alignment in integrated and non-integrated vertical relationships.

The explanation for the key finding is that vertical integration lowers the threat of retaliation when an exchange partner underperforms. For instance, in an integrated vertical relationship it is less likely that a buyer will fire a supplier if the supplier underperforms than in a non-integrated vertical relationship. Internal relationships are more forgiving than external relationships, which affects the extent to which incentives of foresighted exchange partners are aligned and as a consequence the amount of effort parties put into the relationship. This mechanism is currently not considered in theories of the firm, but can explain why external parties may outperform internal parties even when contracts are incomplete.

If vertical integration does not necessarily lead to more incentive alignment, why would vertical integration ever be optimal? I use a formal model in the second part of this chapter to address this question. First, I formally show for a very generic set of relationships that even if contracts are incomplete incentive alignment can be greater in external than internal relationships given differences in forgiveness, supporting the findings of the fieldwork. In the model this results in more effort and higher quality goods in external than internal relationships. Second, I explore the role of technical uncertainty in determining when it is optimal to vertically integrate. I distinguish between controllability of the task and easiness of the task, and precisely define both. Interestingly, I find that more technical uncertainty does not necessarily lead to vertical integration, regardless of whether it is defined as controllability or easiness. I present the formal model after my discussion of the fieldwork.

2.2. Methods: Fieldwork

2.2.1. Setting

I begin with a qualitative method to investigate the effect of firm boundaries on incentive alignment for two reasons. First, I am primarily interested in *how* firm boundaries influence the incentives of parties in vertical relationships. Yin (1994) suggests that a qualitative method is especially useful to address how questions, because it allows for the possibility of finding mechanisms that are not considered at the beginning of a research project. Second, most of what we know about incentive consequences of firm boundaries is based on formal and informal theorizing. Little is based on direct observation. More progress may come from using a different approach than from a similar approach.

I use theoretical, not random, sampling to select cases (Eisenhardt, 1989*b*). If I were to find differences in incentive alignment between integration and non-integration, then selection would be a main alternative explanation. Are these differences between integration and non-integration due to the fundamentally different nature of each governance mode, or are these due to the different things organized under integration and non-integration (i.e. other products, services, or transactions)? In order to address the first possibility and rule out the second option as much as possible, I focus on settings of plural sourcing.

Plural sourcing is defined as an instance where a firm makes and buys the same product (Puranam et al., 2006). Because the nature of goods and services of the internal and external relationships is similar, we can meaningfully compare the organization of both relationships. Broadly speaking, plural sourcing may occur for two different reasons (Puranam et al., 2006). First, plural sourcing can increase the incentives to perform for both internal and external suppliers. If a firm produces an input in-house in addition to buying from the market, it can more credibly threaten backward integration and hence put more pressure on the external supplier (Porter, 1980). Furthermore, having an internal supplier gives a firm detailed cost and performance estimates to better monitor its outside supplier (Harrigan, 1985, 1986). Likewise, an outside supplier provides an ideal benchmark for an internal supplier (Jacobides and Billinger, 2006). Underlying these arguments is that simultaneously having an internal and external supplier increases competitiveness, leading to better performance (Puranam et al., 2006). A second reason is that through plural sourcing distinctive knowledge can be transferred between internal and external suppliers leading to better performance for both (Dyer and Singh, 1998; Helper et al., 2000; Dyer and Hatch, 2006).

These reasons suggest that plural sourcing relationships may be different than non-plural sourcing relationships. Hence, I explicitly trade off internal and external validity. The specific findings from this qualitative study may perhaps not generalize beyond the research setting, but the underlying mechanisms could. In part, I use a formal model in the second part of this chapter to explore the implications if the uncovered mechanisms are generalizable.

I approached companies with the assistance of the Dutch Association for Purchasing Management (NEVI). The sampling frame was NEVI's membership list. I contacted only multi-business unit companies, in order to compare vertical relationship between internal units with those between external units. Eight companies agreed to participate. For two companies I analyzed two instances of plural sourcing and for the other companies one. For confidentiality reasons I cannot disclose the names of the participating companies. They are active in different industries, including chemicals, energy, basic materials, and transportation. All have international operations, though the buying and supplying units of the studied vertical relationships are based in The Netherlands.

I conducted 27 interviews with 30 respondents (i.e. some interviews had multiple respondents). Respondents were selected on the basis of their knowledge of the internal and external relationships. Respondents were promised anonymity to encourage sincere answers. The interviews were semi-structured and questions were comparative, i.e. explicitly asking to compare the internal and external relationships. On average an interview lasted 70 minutes, with a minimum of 50 and a maximum of 100 minutes. I took extensive notes and most interviews were recorded. Most interviews were transcribed and notes were processed within 24 hours.

2.3. Results: Fieldwork

2.3.1. Key Finding: Higher Cooperation in External than Internal Vertical Relationships

Through my interviews I find that, generally, the degree of cooperation is higher in external than internal vertical relationships. This finding reflects the broad consensus among the respondents, both those from the buying units and those from the supplying units. Some typical responses are:

> "It is easier to do business externally. [...] With renegotiations the internal supplier uses the fact that we cannot leave. They refuse to give in much longer than the external supplier."
>
> "Internally is less pleasant because often one of the two parties feels disgruntled because they have to buy internally."
>
> "Companies, or external suppliers, are more.... obliging I do not know, but more in a service providing role than our internal supplier."
>
> "It [doing business] is more difficult with an internal supplier."

I use "degree of cooperation" here to capture the willingness of exchange partners to behave in a way that is mutually beneficial (Heide and John, 1992). This includes the extent to which exchange partners are flexible and responsive. More specifically, respondents indicate that external partners are typically easier to negotiate with, better able to adjust their product offering to changes in customer demands, more responsive in providing customer service, and more detailed in their planning for the relationship. Exchange partners in external relationship have greater incentive alignment (or act as if incentives are better aligned) than in internal relationships.

What is interesting about this finding is not that cooperation can be difficult within firms, but that it often seems much harder than between firms. This is in direct contrast to the assumptions underlying transaction cost economics, which of all theories of the firm speaks most directly to these issues. In transaction cost economics firms provide incentive alignment and facilitate cooperation. Williamson (1975, p. 109) summarizes this view as follows:

> "Furthermore, suppose that all contracts were assigned to the mainly autonomous contracting, mainly hierarchical, or ambiguous categories, and frequency distributions for contracts of each type were drawn with respect to the degree of cooperation. I submit that while the resulting distributions would overlap, the modal degree of cooperation for the hierarchical distribution would surely exceed that for the autonomous distribution."

In transaction cost economics, the cooperation advantages of internal relative to external relationships should be most pronounced when bilateral adaptation is required (Williamson, 1991). If parties need to simultaneously adapt to changing circumstances and their production assets are highly specific to each other, then the potential for opportunism and hold-up is greatest. Given better incentive alignment, internal organization should provide adaptation benefits, flexibility, and responsiveness. However, I find that even when mutual adaptation is required the degree of cooperation tends to be greater in external than internal relationships (see for example the first quote about renegotiations).

While my findings differ from prior theoretical literature, they are consistent with prior empirical literature. In particular, my findings echo those of Eccles and White (1988), who study transfer pricing within multi-unit businesses. Eccles and White also find that internal parties prefer to deal with outsiders if they have a choice.[1] Why is it that incentive alignment often appears higher in external than internal vertical relationships, the opposite of what several theories of the firm assume?

[1] In contrast to their study, I focus exclusively on plural sourcing relationships ensuring comparability of the internal and external relationship.

2.3.2. Key Mechanism: Extent to which Future Business is Guaranteed

Incentive alignment is often higher in external than internal vertical relationships because it is more difficult to terminate an internal than an external relationship. If termination is less likely, the incentives to perform are lower. Two of the quotes above already hint at this key difference between internal and external relationships. Some interviewees further explain that there is often no choice but to continue the internal relationship:

> "The competition is greater externally. There you make a free choice. Internally you do not have a free choice. [...] You cannot walk away. You have to sell. The same goes for buying. You have to buy. With an external you can always say, no, I no longer do it. You cannot say that to an internal."
>
> "But what you see is that there is no alternative [with an internal supplier]. It is not the case that if he [internal supplier] performs poorly, I will go to his neighbor [other supplier]. You observe that the pressure to change is not very big [for an internal supplier]. This is a completely different attitude towards a customer than an external party has."

On the other hand, the decision to continue or discontinue external relationship depends more strongly on performance outcomes:

> "It is simple with an external party. [...] It could be that an external party tries to cheat somewhat. They can do that once or twice, but a third time... [...]. In other words, you continue with parties who treat you well and fairly, and parties who try to be smart by probing the boundaries of the requirements... Well, you say goodbye to those."

If a relationship has a low termination probability even if its performance is low, then the prospect of future business does not provide a strong incentive for exchange partners to perform. It is well known that if future business is awarded conditional on cooperation, parties have a strong motivation to perform because good outcomes get rewarded (with future business) and bad outcomes are punished (by withholding future business) (Heide and Miner, 1992). Future outcomes affect current behavior, which is also known as the shadow of the future effect (Axelrod, 1984). This effects hold if there is uncertainty about the future, but loses its power if the future becomes more certain or independent of actions. Given that internally future business is more or less guaranteed while externally it has to be earned, it follows that the drive to perform is greater in external relationships than in internal relationships. Because an internal party "cannot walk away from" or "cannot leave" another internal party, cooperation tends to be higher in external than internal vertical relationships.

The notion that future outcomes affect current behavior has been developed most precisely in game theory through the study of repeated games. The canonical problem in this stream of research is the prisoner's dilemma in which two players can each choose to "cooperate" or "defect". The payoffs of the game are structured such that it is in each player's best interest to defect, regardless of what the other player does. However, if both players follow this strategy they will end up with less than if they had both cooperated. Furthermore, for each player the best outcome is to individually defect while the other is cooperating, leaving the unilateral cooperator with the worst possible payoff. If this game is just played one round, the rational decision for each player is to defect.

However mutual cooperation is a Nash equilibrium in the sense that no player can do better by unilaterally defecting, if the players interact an infinite number of times and sufficiently value future payoffs relative to immediate payoffs (Fudenberg and Maskin, 1986). Analytically this is similar to a game with an uncertain end date, i.e. after each round there is a small probability that the game is terminated. Under certain conditions this result also holds when the game is played a finite number of rounds if players are uncertain about each other's decision rules or payoffs (Kreps et al., 1982). Let's consider an example of a repeated prisoner's dilemma to clarify the intuition behind these results. Suppose that both players have been cooperating, but one player decides to defect. This leads to an immediate high payoff for that player, in fact the highest possible payoff for a single round. Because it is a repeated game, the other player can retaliate by defecting in the subsequent rounds. The resulting payoffs are lower in comparison to the initial situation of mutual cooperation. A potential defector must therefore weigh the total value of continued cooperation against the short-term gains from defection followed by the long-term loss from punishment. Continued cooperation becomes more attractive as the potential payoffs from cooperation in the future increase relative to the losses from punishment, i.e. as the shadow of the future increases.

Prior empirical research in game theory indeed finds that a greater shadow of the future increases cooperation. For instance, Roth and Murnighan (1978) use several prisoner's dilemmas that are played repeatedly with varying probabilities of continuation. The degree of cooperation is higher when the probability of continuation goes from $p = .105$ to $p = .5$ (19% versus 29.75% in first round plays). There are no significant difference in cooperation when the probability increases from $p = .5$ to $p = .895$. Murnighan and Roth (1983) report similar findings. Likewise, Bo (2005) finds that in prisoner's dilemmas the greater the shadow of the future the higher the levels of cooperation. In the single-shot version the degree of cooperation is around 9%. In the repeated game this goes up to 27% when the probability of continuation is .5 and to 37% when the probability of continuation is .75.

Empirical evidence on the organizational level also supports the effect of the shadow of the future. For example, Heide and Miner (1992) find that the open-endedness of future interactions between buyers and suppliers in the general machinery, electrical and electronic machinery, and transportation equipment industries is positively associated with the degree of flexibility, information exchange, shared problem solving, and restraint in the use of power. Poppo et al. (2008) find that buyer's expectations of continuity are positively related to trust in the supplier in their sample from the electronics, textile, furniture, and fabricated metal products industries.

The future casts a shadow if that future depends on the actions exchange partners take in the present. If partners' actions have little or no effect on the continuation of the relationship, then the shadow of the future loses its incentive effect. Because internally future business is more or less guaranteed but externally it is dependent on performance, incentive alignment can be greater externally than internally.

It is often more difficult to terminate an internal than an external relationship due to formal company policy or informal pressures. First, I find that formal company policy may prescribe that certain goods and services must be bought internally. For example, Eccles and White (1988) document that many transfer pricing policies not only specify which prices should be charged internally, but also come with the explicit provision that internal purchases and deliveries must be made. To the extent that internal relationships are mandated, future business becomes guaranteed and independent of performance. Even if internal transactions are not formally mandated, top management may use various techniques to stimulate internal transactions (Eccles and White, 1988). For example, they could set transfer prices below market prices such that buyers get a cost advantage from buying internally. Or they could require that at least a given percentage of a buyer's requirements is bought internally.

For two reasons top management may insist on internal transactions, even if these transactions seem to underperform external transactions. First, an internal transaction could generate benefits beyond the focal transaction. For example, an internal relationship could be used to maintain essential production knowledge or develop new technologies that are beneficial to other parts of the company. Second, fixed costs are higher for internal compared to external transactions. For example whereas internally fixed costs include the cost of equipment, these are all variable externally from the perspective of the buying unit or top management. Even if the internal transactions are terminated, these fixed costs have to be made. Because fixed costs are sunk for decision making, it is economically optimal to continue the internal relationship if internal variable costs are below the market price. Because in external relationships costs are more variable, the tendency to terminate them when more attractive alternatives are available is higher.

Second, informal pressures make it harder to terminate internal than external relationships. Internal units are part of a larger organization that has shared beliefs. Social relations are essential in maintaining those beliefs and creating strong bonds between colleagues. While being colleagues does not imply that relationships run smoothly (as discussed above), it does create a sense of common purpose and commonality. Because of strong (personal) connections, firing a colleague is harder than terminating a relationship with an external unit. For example, some respondents suggested that in times of economic hardship one prefers to give business to colleagues to help them through hard times. This effect is particularly strong if terminating an internal relationship implies that people will lose their job.

2.3.3. (The Lack of) Compensating Mechanisms

While theories of the firm currently do not incorporate that vertical integration weakens the incentive alignment from the shadow of the future effect, they suggest other mechanisms that could potentially compensate this impact to the extent that incentive alignment would be greater under vertical integration. Two key alternative mechanisms are residual claimancy and dispute resolution. I find that both operate differently in my data than described in theory.

2.3.3.1. Residual claimants. While residual claimancy is important in many theories of the firm (Alchian and Demsetz, 1972; Grossman and Hart, 1986; Aghion and Tirole, 1997), transaction cost economics is most explicit in linking residual claimancy with degree of cooperation within a relationship. The transaction cost economics argument is that internal divisions are not residual claimants and hence “do not ordinarily have pre-emptive claims on their respective profit streams” (Williamson, 1975, p. 29). However, like employees of an internal supply division, employees from an external supplier are usually not residual claimants. As their title indicates, these employees are not the owner of the external supplier. Of course, they may benefit from behaving opportunistically against another firm. However, they will not be able to appropriate all or even most of the resulting gains. Therefore, the incentives to behave opportunistically may not be very different for an employee from an external supply unit than for one from an internal unit.

When discussing the consequences of integration versus non-integration, (Williamson, 1975, p. 29) is explicitly comparing "autonomous contractors" with "internal divisions". As Bolton and Scharfstein (1998) have pointed out, in many situations the actual trade-off is different. Often ownership and control is separated not only within the internal party but also within the external party. In these cases, the key decision is whether to organize the unavoidable haggling and bargaining between managers (or employees) of different firms or between managers of the same firm. At the same time, one would expect the assumptions of transaction cost economics to better describe situations where external parties are managed by their owners (Hart and Holmström, 2008).

The vertical relationships that I studied resemble more those described by Bolton and Scharfstein (1998) than by Williamson (1975). Managers and employees (but not owners) were active in the internal units. Similarly, owners were not directly involved in the external units as these were run and operated by managers and employees. All participants to the relationship, internal and external, were not residual claimants. This helps explain the absence of a cooperation advantage for internal relationships relative to external relationships.

2.3.3.2. Authority as dispute resolution. Another proposed transaction cost advantage of firms relative to markets is the presence of authority to resolve disputes more efficiently internally than can be done externally. As Williamson (1975, p. 30) notes, internal organization is "able to settle many such disputes by appeal to fiat - an enormously efficient way to settle instrumental differences." Internal divisions can appeal to a common boss, who will dictate a solution. This authority originates in the employment contract (Simon, 1951) and from the unwillingness of legal courts to hear internal disputes (Williamson, 1991). External vertical relationships have no common boss. They often have to rely on costly legal courts as it is not always possible to agree on a neutral arbiter. Going to court is costly and time consuming.

I find that internally fiat is hardly ever used to resolve conflicts. In most settings authority is used less than once a year to resolve conflicts. In no setting is a common boss asked to settle disputes more than three times a year. As respondents note,

> "In principle we do not do that [asking a common boss to arbitrate]. We always let the people who run the business sort it out. Thus, it is not escalated all the way up the chain. This is not the purpose."
>
> "No conflicts are escalated to the level of the first common boss, because he has other things to do. It is a sign of weakness to escalate all the time."
>
> "Escalations are used to resolve problems. These conflicts are typically about transparency in costs structure. However, it is very rare for these conflicts to reach the common boss. This happened only three times in the last two years."
>
> "In case of a conflict, it is very rare to go to a board member or to the CEO. If you go to the CEO, then you are doing something wrong."

It is not rare to use escalation to solve internal problems. For example, if a dispute arises between two employees of an internal buying and selling unit, they may go to their respective bosses. Sometimes the problem is escalated even further, i.e. to the bosses of the bosses. However, it rarely (if ever) reaches a boss who is hierarchically responsible for both the buying and selling unit. This is typically a board member or CEO who is the first common boss in a multi-business unit firm. Conflicts are resolved through negotiations, not through fiat.

Escalation is also the typical way of resolving disputes between firms. As a manager describes,

> "An escalation is initiated. First, the account manager tries to solve it with the purchasing manager and business representatives. If that is not successful, then it goes up one level. If that is again not successful,

> then it goes up yet another level. Thus, we have a kind of escalation tree."
>
> "Externally escalations are also used to resolve problems. Of course, these problems cannot reach a common boss."

Why is fiat hardly ever used internally? A typical response was that top management has other things to do. In addition, it was felt that these were exactly the issues for which middle management was hired. It is part of their job. As some respondents observed, if a middle manager has to rely on top management too often to resolve conflicts, then the middle manager is seen as ineffective.

Also, the cost of using the hierarchy to resolve conflicts is not negligible. For one thing, top management needs to be informed about the nature of the problem. Top management needs to obtain substantial information to be able to come up with an appropriate solution. This is neither easy, nor cheap. In case of a dispute between two divisions, each party can at best offer a subjective interpretation of the events at hand, and at worst a grossly distorted version in an attempt to benefit maximally. Therefore, it is essential that top management spends resources to obtain accurate information. Information costs go up with the number of hierarchical layers top management is removed from the conflict. A manager notes,

> "The board does not know what is going on. Both parties are not happy with their decisions."

The key problem here is asymmetric information. In the event of an interdepartmental dispute, the divisions are better informed about the dispute and appropriate solutions than authority. Only when authority is able to rebalance some of the information asymmetry can authority fulfill a meaningful role in dispute resolution (Aghion and Tirole, 1997).

Williamson (1975) suggests that conflict resolution is more efficient internally because of the usage of fiat. I find that fiat is hardly used at all. While both statements could be consistent with each other, I find in my data that no conflict resolution advantages of internal organization are present to the extent that they make internal organization smoother than external organization. One reason for this could be that I exclusively focus on internal transactions within multi-business unit firms. While such firms are very common and represent a large share of the economy, fiat may be more effective in firms with less hierarchical levels. Thus, transaction cost economics may describe best situations where external parties are owner-managed (see above) and internal organization consists of a limited number of hierarchical levels.

While these findings highlight some important boundary conditions for transaction cost economics, they also have implications for theories of the firm that are based on asset ownership. For example, in property rights theory integration is defined as asset ownership (Grossman and Hart, 1986; Hart and Moore, 1990). A vertically integrated transaction is one between employees and owners of an asset. In practice a vertically integrated transaction, i.e. a transaction within a single firm, is often one between employees and different employees, neither of whom are asset owners. In such cases neither side has any a priori authority or decision making power over the other. Hence, in future work on theories of the firm we must carefully distinguish between two meanings of vertical. One indicates the flow of goods and the other indicates the hierarchical or reporting relationship. Often these two refer to different relationships.

2.3.4. Alternative explanations

I have argued that the degree of cooperation is higher in the external than internal relationships that I studied because internal relationships are less likely to be terminated. I consider two alternative explanations for the observed difference in degree of cooperation.

The first alternative explanation is that in all the investigated relationships the scope of opportunism is small. If this is true, then transaction cost economics predicts that an external relationship is more efficient than an internal relationship (Williamson, 1975). It would also imply that all governance mode choices of the internal relationships in my sample were inefficient (at least from the perspective of a single relationship). Actually, it turns out that many of the relationships in my sample are characterized by high asset specificity. For example, in one relationship knowledge was required that was highly specific to the processes and services in that relationship. In another, the internal supplier had assets dedicated to the internal buyer on such a scale that these assets could not be easily be relocated to alternative relationships. Because asset specificity increases the scope of opportunism, internal relationships should be preferred under these conditions (Klein et al., 1978; Williamson, 1985). Furthermore, even if it were true that all internal governance mode choices were inefficient, then this would not invalidate the key mechanism.

The second alternative explanation is that observed differences in the degree of cooperation occur because the vertical relationship is part of plural sourcing relationships. If one were able to compare (similar) internal and external non-plural sourcing relationships, then perhaps a cooperation advantage for external relationships would not be found. This argument does not question the internal validity (as above), but raises questions about the external validity. On the basis of my data it is difficult to claim that cooperation should always, or even most often, be higher externally than internally (and this is also not the point). However, the key mechanism - the degree which future business is guaranteed - should still provide cooperation benefits to external *relative* to internal relationships. None of the reasons put forward for why it is harder to terminate an internal relationship is unique to plural sourcing relationships. Whether the effect is such that external relationships are uniformly preferred is not clear (and also not likely), the point is that they become *relatively* preferred if the mechanism is at work.

More generally, the key insight from this study is not that the absolute level of cooperation is higher externally than internally. As a matter of fact, such a claim is always hard to defend without evidence from a large sample. The more important point is that this study isolates a mechanism which explains some empirical observations that are difficult to reconcile with prior theories of the firm.

2.4. Methods: Formal Model

In this section I build a formal model to show that the suggested mechanism - the extent to which future business is guaranteed - is a sufficient explanation for observed cooperation differences between internal and external vertical relationships. The advantages of a formal model for this purpose are threefold. First, it provides clarity on the main constructs in a way that informal language may not be able to. Second, it helps us understand the extent to which the findings are generalizable to other settings. Third, it facilitates comparison with other theories of the firm because assumptions are made explicit.

The setup of the model is similar to Baker et al. (2002), which is the key reference in the domain of future business and the theory of the firm. I cannot use their exact model for two reasons. First, by construction in their model agents put in similar effort under integration as non-integration. I am precisely interested in how effort differs between integration and non-integration. Second, in their model integration is defined on the basis of asset ownership. Because I want to model internal and external relationships between parties that use but do not own an asset, I cannot rely on asset ownership as the defining characteristic of integration. Instead, based on my field observations I define integration as a reduced probability that a relationship will be terminated given low performance. This is the key distinction between our models. Below I provide more detail on the definition of integration.

2.4.1. The Model

I consider an upstream (U) and a downstream (D) party who can choose to trade with each other. Both are risk-neutral. Each period the upstream party produces a good by choosing a level of effort e at cost $c[e]$. Upstream's cost is increasing in effort ($\frac{\partial c[e]}{\partial e} > 0$). I assume it does so at an increasing rate ($\frac{\partial^2 c[e]}{\partial e^2} > 0$). If upstream puts in no effort, I assume that the cost is zero ($c[0] = 0$). Upstream's effort influences the value of the good for downstream (Q). This value is high (Q_H) with probability $\gamma + q[e, \alpha]$

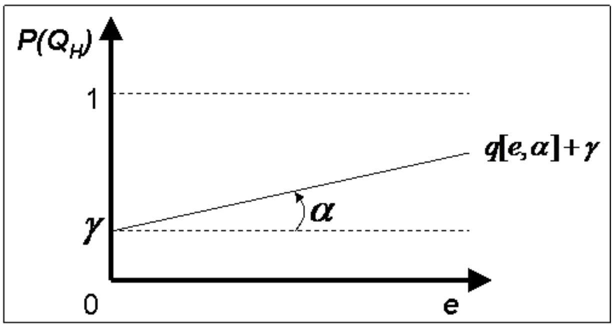

Figure 2.1. The effect of effort on the probability of high value

and low (Q_L) with probability $1 - \gamma - q[e, \alpha]$, where $Q_L < Q_H$.[2] More effort increases the probability of high value ($\frac{\partial q[e,\alpha]}{\partial e} > 0$). I assume effort has non-increasing marginal returns ($\frac{\partial^2 q[e,\alpha]}{\partial e^2} \leq 0$). The parameters γ and α capture different aspects of the extent to which the link between inputs and outcomes is uncertain. As I will show below, this distinction matters for the optimal threat level.

Figure 2.1 illustrates the difference between γ and α. It shows the probability of high value, $\gamma + q[e, \alpha]$, as a function of effort. The parameter γ is the probability of high value when upstream puts in no effort. It is the baseline level of success or the **easiness of the task**. An increase in γ leads to a vertical shift of the line $\gamma + q[e, \alpha]$. The parameter α influences the marginal effect of effort on the probability of high value. It is the extent to which effort matters for the outcome of the task or the **controllability of the task**. A higher α implies a higher marginal effect and leads to a steeper $q[e, \alpha]$ (and $\gamma + q[e, \alpha]$). Hence, the cross partial derivative is positive: $\frac{\partial^2 q[e,\alpha]}{\partial e \partial \alpha} > 0$. Because a non-zero cross partial derivative implies that both partial derivatives are nonzero, and given $q[0, \alpha] = 0$, α has a positive effect on the probability of high value while holding effort constant ($\frac{\partial q[e,\alpha]}{\partial \alpha} > 0$).

Like Baker et al. (2002), I assume that effort is only observable to upstream and that no outsiders can verify the good's quality. Hence, it is not possible to write an enforceable formal contract on the input or output of the production process. Instead I will focus on relational contracts, informal agreements sustained by the value of

[2]For convenience, I define value (Q) as binary and let effort influence the probability of high value. It is possible to rewrite the model such that value is continuous and effort influences value positively (and stochastically).

future relationships (Baker et al., 2002). In the tradition of the theory of the firm, I acknowledge the role of formal contracts but focus on those aspects of the exchange that are non-contractible. Thus in this model Q_H captures all those elements that are non-contractible (due to non-observability of effort or non-verifiability of quality), while Q_L includes anything that can be addressed in a formal contract.

Downstream can compensate upstream through a combination of a fixed fee before production ($w \geq 0$) and a bonus after production (b). I distinguish between a bonus for low quality (b_L) and one for high quality (b_H), where $0 \leq b_L \leq b_H$. This incorporates the special cases where the low quality bonus is the same as the high quality bonus ($b_L = b_H$), and where the low quality bonus is absent ($b_L = 0$). If the parties cannot agree on a compensation scheme, they do not trade with each other. Instead they receive fixed payoffs per period of u^O for upstream and d^O for downstream. I focus on those instances where the outside opportunities are less desirable than efficient trade, but more attractive than when upstream has no incentive to perform.[3] Defining $s^O \equiv u^O + d^O$ and $\Delta Q \equiv Q_H - Q_L$, we have $Q_L < s^O < \max_e Q_L + (\gamma + q[e, \alpha])\, \Delta Q - c[e]$.

In a one-time interaction, the up front fee does not provide upstream any performance incentive and leaves downstream with the risk of moral hazard. At the same time, upstream faces the risk of downstream not paying the promised bonus after production. In the static game, upstream and downstream will not trade with each other given the outside opportunities. However, the prospect of repeated interactions can provide the right incentives for upstream and downstream to trade with each other even if formal contracts are not enforceable. For each party the cost of cheating (putting in too little effort or reneging on the bonus) now includes the potential loss in value of the future relationship. In the repeated game, upstream and downstream will trade with each other under certain conditions. I will precisely specify these conditions below.

[3] If outside opportunities are always less desirable, then it is never optimal to break the relationship. While such cases may exist, this model would not provide much insight.

2.4.2. Probabilistic Trigger Strategy

Based on my field observations, I model the effect of vertical integration as a decrease in the probability of downstream terminating the relationship given that upstream produced a low quality good. Let $p = P[\text{Relationship ends}|Q_L]$, so that we have $p_{Vertical-integration} < p_{Non-integration}$. Thus, the threat of retaliation is lower under vertical integration than non-integration. I assume that if a relationship ends, parties do not trade with each other again and receive their outside payments forever after. This is similar to a trigger strategy with the important qualification that it is probabilistic. Downstream will terminate the relationship only if upstream fails to produce high quality, but downstream may not always end the relationship if upstream delivers low quality.[4]

Given a common discount factor $\delta \in [0, 1)$, we have all elements in place to specify the conditions under which the parties will enter into a relational contract. If the parties decide to trade with each other, downstream pays upstream w at the beginning of the period. After production, the size of the bonus and continuation decision depends on the good's quality. If upstream produces Q_H, downstream pays upstream b_H and they continue the relationship in the next period. If upstream produces Q_L, one of two things happens. First, with probability $1 - p$ downstream pays upstream b_L and the relationship continues. Second, with probability p downstream pays no bonus and the relationship ends. In all instances downstream gets the good, which is plausible for all goods whose quality becomes known only during usage (e.g. services or complex

[4] This is similar to Levin's (2003) termination contracts, in which a relationship continues if a principal's (i.e. downstream's) performance assessment is above a certain threshold level. If performance falls below the threshold, the relationship ceases forever. In his model performance is continuous and the threshold level is optimally chosen given that p equals one. I take a related approach. Given an exogenous threshold (Q_L), I explore which p is optimal.

products). Thus,

$$
\begin{aligned}
&Q_H \text{ with probability } \gamma + q[e,\alpha] \Rightarrow b_H \text{ and relationship continues}\\
&Q_L \text{ with probability } 1-\gamma-q[e,\alpha] \Rightarrow\\
&\qquad\begin{cases} b_L \text{ and relationship continues with probability } 1-p \\ \text{no bonus and relationship ends and with probability } p \end{cases}
\end{aligned}
$$

Let U^R denote upstream's net present value of entering a relationship and U^O the net present value of its outside option. We have:

$$
\begin{aligned}
U^R[e,p,\alpha,\gamma] &= w + (\gamma + q[e,\alpha])\, b_H + (1-\gamma-q[e,\alpha])\left((1-p)\, b_L + p\delta U^O\right) - c[e] \\
&\quad + (1-(1-\gamma-q[e,\alpha])\, p)\, \delta U^R[e,p,\alpha,\gamma]
\end{aligned}
$$

Upstream will enter into a relationship if and only if:

$$U^R[e,p,\alpha,\gamma] > U^O \tag{2.1}$$

Let D^R denote downstream's net present value of entering a relationship and D^O the net present value of its outside option. We have:

$$
\begin{aligned}
D^R[e,p,\alpha,\gamma] &= Q_L + (\gamma + q[e,\alpha])\,(\Delta Q - b_H) + (1-\gamma-q[e,\alpha])\left(p\delta D^O - (1-p)\, b_L\right) - w \\
&\quad + (1-(1-\gamma-q[e,\alpha])\, p)\, \delta D^R[e,p,\alpha,\gamma]
\end{aligned}
$$

Downstream will enter into a relational contract if and only if:

$$D^R[e,p,\alpha,\gamma] > D^O \tag{2.2}$$

Define total surplus of the relationship as $S^R \equiv U^R + D^R$, and total surplus of the outside options as $S^O \equiv U^O + D^O$:

$$
\begin{aligned}
S^R[e,p,\alpha,\gamma] &= Q_L + (\gamma + q[e,\alpha])\, \Delta Q + (1-\gamma-q[e,\alpha])\, p\delta S^O - c[e] \\
&\quad + (1-(1-\gamma-q[e,\alpha])\, p)\, \delta S^R[e,p,\alpha,\gamma]
\end{aligned}
$$

Note that total surplus generated in the relationship does not depend on the fixed fee and bonuses, provided that boundary conditions 2.1 and 2.2 hold. In the appendix I specify the constraints imposed on the fixed fee and bonuses from these boundary conditions. From the same boundary conditions it follows that:

$$S^R[e, p, \alpha, \gamma] > S^O \tag{2.3}$$

In the next section I explore the optimal values for effort (e) and threat level (p).

2.5. Results: Formal Model

2.5.1. Optimal Effort

Through the fieldwork I find that upstream parties put in less effort if they are vertically integrated than if they are not. Upstream's effort is positively related to the threat of terminating the relationship in the event of low performance. In this section I derive this result from the model.

Upstream will choose optimal effort to maximize its payoffs:

$$\max_e U^R[e, p, \alpha, \gamma]$$

If $q[e, \alpha]$ and $c[e]$ are twice differentiable, let the first order condition define the implicit function F^1:

$$\begin{aligned} F^1[e; p, \alpha, \gamma] &\equiv \tfrac{\partial U^R[e,p,\alpha,\gamma]}{\partial e} = 0 \\ &= \tfrac{\partial q[e,\alpha]}{\partial e}\left(b_H - (1-p)\, b_L + p\delta\left(U^R[e, p, \alpha, \gamma] - U^O\right)\right) - \tfrac{\partial c[e]}{\partial e} \\ &\quad + \left(1 - (1 - q[e, \alpha])\, p\right)\delta \tfrac{\partial U^R[e,p,\alpha,\gamma]}{\partial e} \\ &= \tfrac{\partial q[e,\alpha]}{\partial e}\left(b_H - (1-p)\, b_L + p\delta\left(U^R[e, p, \alpha, \gamma] - U^O\right)\right) - \tfrac{\partial c[e]}{\partial e} \end{aligned} \tag{2.4}$$

The second order condition is:

$$\begin{aligned}\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e} &= \tfrac{\partial^2 q[e,\alpha]}{\partial e^2}\left(b_H-(1-p)\,b_L+p\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)-\tfrac{\partial^2 c[e]}{\partial e^2}\\ &\quad +\tfrac{\partial q[e,\alpha]}{\partial e}p\delta\tfrac{\partial U^R[e,p,\alpha,\gamma]}{\partial e}\\ &= \tfrac{\partial^2 q[e,\alpha]}{\partial e^2}\left(b_H-(1-p)\,b_L+p\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)-\tfrac{\partial^2 c[e]}{\partial e^2}<0 \qquad (2.5)\end{aligned}$$

Proposition 1. *Optimal effort is increasing in the threat level (*$\frac{\partial e^*}{\partial p}>0$*).*

See the appendix for the proof. The first order condition can be written as $\frac{\partial q[e,\alpha]}{\partial e}\left(b_H-(1-p)\,b_L+p\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)=\frac{\partial c[e]}{\partial e}$, or marginal benefit equals marginal cost. An increase in the threat level increases the marginal benefit of effort, but it does not affect its marginal cost. Marginal benefit increases because the difference between upstream's payoff in case of high quality and its expected payoff in case of low quality increases. It follows that optimal effort must increase.

Hence, optimal effort increases with a stronger threat of retaliation. If this threat is reduced through vertical integration, then this model predicts lower effort if upstream is vertically integrated than if it is not. This is consistent with my empirical observations. Note that this effort is spent on *non-contractible* dimensions.

Proposition 2. *Optimal effort is increasing in the controllability of the task (*$\frac{\partial e^*}{\partial \alpha}>0$*).*

See the appendix for the proof. An increase in the controllability of the task is defined as an increase in effort's marginal benefit. The parameter α does not affect marginal cost. Hence, optimal effort must increase with an increase in controllability. The model predicts that more effort will be spent on a high than as a low controllable task.

Proposition 3. *Optimal effort is increasing in the easiness of the task (*$\frac{\partial e^*}{\partial \gamma}>0$*).*

See the appendix for the proof. While an increase in γ does not affect the marginal effect of effort on the probability of high value, it does further increase the attractiveness of the relationship relative to the outside option ($U^R[e, p, \alpha, \gamma] - U^O$). This is because it becomes more likely that high quality goods are produced in the relationship. As γ does not influence marginal cost, an easier task leads to more effort. Thus, this model suggests that effort is higher for an easy than a hard task.

2.5.2. Optimal Threat Level

Given that effort is lower if upstream and downstream are integrated than if they are not, is it ever optimal to vertically integrate? Another way of asking the same question, if stronger threats lead to more effort, why would one ever set p below the maximum threat possible? I argue below that setting a high threat level has the advantage of encouraging high effort, yet comes with the disadvantage of potentially terminating a valuable relationship. I will show that the controllability and easiness of the task influence this trade off. I find that the relationship between task controllability and task easiness on the one hand and optimal threat level on the other hand is not unidirectional. For some functional forms and some values of the exogenous parameters, easiness and controllability of the task are positively related to the optimal threat level. Under other conditions, easiness and controllability of the task are negatively related to the optimal threat level. Somewhat counterintuitively, it follows that less controllable and harder tasks are *not* necessarily associated with vertical integration.

In the analysis above p is treated as exogenous, here we need to treat p as endogenous. The problem is to choose p to maximize surplus subject to the constraint that upstream chooses e to maximize U^R:

$$\max_p S^R[e^*, p, \alpha, \gamma]$$

Define the first order condition as the implicit function F^2, taking into account that e^* is a function of p.

$$F^2[p;\alpha,\gamma] \equiv \frac{dS^R[e^*,p,\alpha,\gamma]}{dp} = \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial p} + \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\frac{\partial e^*}{\partial p} = 0 \tag{2.6}$$

From this first order condition we can clearly see the two opposing effects an increase in p has on total surplus: a termination ($\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial p}$) and an incentive ($\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\frac{\partial e^*}{\partial p}$) effect. The **termination effect** simply means that a relationship is more likely to be terminated (holding effort constant). Upstream and downstream are more likely to end up with their outside options. Because these outside options are less valuable (see 2.3), the termination effect must be negative ($\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial p} < 0$). Because $\frac{\partial e^*}{\partial p} > 0$ as shown above, it follows from the first order condition that $\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}$ is positive. This implies that upstream will always put in effort below the social optimum, given the setup of this model. The **incentive effect** implies that an increase in p will bring effort closer to the social optimum. The optimal threat level is such that these two opposing effects cancel out exactly.

The second order condition is:

$$\begin{aligned} \frac{\partial F^2[p;\alpha,\gamma]}{\partial p} &= \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p^2} + \left(\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial p} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\frac{\partial e^*}{\partial p}\right)\frac{\partial e^*}{\partial p} + \\ &\quad \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\frac{\partial^2 e^*}{\partial p^2} < 0 \end{aligned} \tag{2.7}$$

In appendix A, I show why it is difficult to determine the sign of $\frac{\partial p^*}{\partial \alpha}$ and $\frac{\partial p^*}{\partial \gamma}$ for very generic functional forms. The main intuition behind this is as follows. I consider here the case of $\frac{\partial p^*}{\partial \alpha}$. The same logic applies to $\frac{\partial p^*}{\partial \gamma}$. An increase in the controllability of the task (α) will lead to a higher optimal threat level (p^*) if the incentive effect becomes stronger relative to the termination effect. Likewise, a more controllable task will lead to a lower optimal threat level if the incentive effect becomes weaker relative to the termination effect. Simply put, we will see stronger punishment if the net benefits from punishment go up. We will observe weaker punishment if the net benefits of punishment go down. Without further restrictions on the functional forms or on the

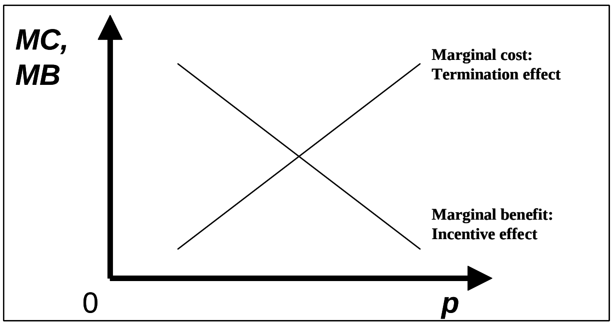

Figure 2.2. The termination and incentive effect of threat level as marginal cost and marginal benefit.

values of the exogenous parameters it is hard to determine whether the termination and incentive effect become weaker or stronger with an increase in α, let alone their relative movement.

For example, the effect of α on the *termination effect* is $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \alpha}$. When controllability increases, the chance of low quality goes down. It becomes less likely that a relationship is terminated, holding p constant. At the same time, an increase in controllability also makes the relationship more valuable. The potential loss if a relationship is terminated is higher. If the relative strengths of these opposing effects are unknown, we cannot infer how changes in the controllability of the task impact the termination effect. Likewise, a threat has an *incentive effect*, because a) the marginal effect of upstream's effort on surplus is positive as upstream will choose a level of effort below the social optimum ($\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} > 0$), and b) a stronger threat will lead upstream to put in more effort ($\frac{\partial e^*}{\partial p}$). The effect of controllability on the incentive effect is $\left(\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \alpha} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2} \frac{\partial e^*}{\partial \alpha}\right) \frac{\partial e^*}{\partial p} + \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} \frac{\partial^2 e^*}{\partial p \partial \alpha}$. If a task becomes more controllable, optimal effort will go up ($\frac{\partial e^*}{\partial \alpha} > 0$). However, it is not clear whether a) the marginal effect of upstream's effort on surplus will increase or decrease ($\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \alpha} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2} \frac{\partial e^*}{\partial \alpha}$), and b) whether a stronger threat will lead upstream to put in extra effort to a similar degree ($\frac{\partial^2 e^*}{\partial p \partial \alpha}$). The change in the incentive effect is indeterminate. If we cannot infer to how the termination and incentive effect change individually, it is not possible to determine their joint outcome.

We can interpret the termination effect as the marginal cost of the threat level (p). The incentive effect is the marginal benefit of threat level. See Figure 2.2 for a graphical representation. The optimal threat level is where marginal cost equal marginal benefit. This is where the termination and incentive effect intersect. If we want to explore how controllability affects the optimal threat level, we need to understand how controllability affects the marginal cost and marginal benefit. If marginal cost increase (i.e. the termination effect shifts up) while holding marginal benefit constant, then the optimal threat level decreases. If marginal benefit increases (i.e. the incentive effect shifts up) while holding marginal cost constant, then the optimal threat level increases. If controllability affects both marginal cost and marginal benefit and moves them in the same direction (i.e. both up, or both down), then we can only make predictions about the shift in the optimal threat level if we know the relative movement of the termination and incentive effect. As explained above, controllability does affect both marginal cost and benefit. Yet, it is not clear in which direction, let alone their relative movement. As such, we cannot predict how the intersection of the termination and incentive effect will change as a result of changes in controllability. We cannot infer how optimal threat level changes.

To get some traction of the problem, I focus next on a subset of functional forms. Specifically, I assume that the probability of high value is linear in effort ($\frac{\partial^2 q[e,\alpha]}{\partial e} = 0$) and the rate at which the cost function changes with effort is constant ($\frac{\partial^3 c[e]}{\partial e^3} = 0$).

Proposition 4. *The condition* $\left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]} - p\delta\right)\left(S^R[e^*, p, \alpha, \gamma] - S^O\right) > \Delta Q$ *is necessary but not sufficient for the optimal threat level to be decreasing in the controllability of the task (*$\frac{\partial p^*}{\partial \alpha} < 0$*).*

The proof is in the appendix. Given the restrictions on the functional forms, the incentive effect is higher for more controllable tasks. If controllability goes up, upstream's effort will have a higher marginal impact on total surplus and upstream's effort will be more responsive to changes in the threat level. The optimal threat level goes up if the incentive effect increases. For the optimal threat level to go down, the termination effect must not only become stronger but must become stronger to the extent that it offsets the increase in the incentive effect. If $\left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]} - p\delta\right)\left(S^R[e^*, p, \alpha, \gamma] - S^O\right) > \Delta Q$, the termination effect becomes stronger with an increase in the controllability of the task. Hence, this condition is necessary but not sufficient for the optimal threat level to be decreasing in the controllability of the task. While it is possible to state the exact necessary and sufficient condition for a decreasing optimal threat level with controllability, this condition is too long to be very informative.

Proposition 5. *The condition* $\left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]} - p\delta\right)\left(S^R[e^*, p, \alpha, \gamma] - S^O\right) > \Delta Q$ *is necessary but not sufficient for the optimal threat level to be decreasing in the easiness of the task* ($\frac{\partial p^*}{\partial \gamma} < 0$)*.*

The proof is in the appendix. Given the restrictions on the functional forms, the incentive effect is again higher for easier tasks. For easier tasks, upstream's marginal effort will have a stronger effect on total surplus. Also, upstream will increase effort more as a result of an increase in the threat level. For the optimal threat level to go down, the termination effect must become stronger to the extent that it compensates the increase in the incentive effect. The termination effect becomes stronger as a task becomes easier if and only if $\left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]} - p\delta\right)\left(S^R[e^*, p, \alpha, \gamma] - S^O\right) > \Delta Q$. Hence, this condition is necessary but not sufficient for the optimal threat level to be decreasing in the easiness of the task. The exact necessary and sufficient condition for a decreasing optimal threat level with easiness can be stated, but again is too long to provide much insight.

One of the interesting results of this model is that less controllability and less easiness do not necessarily lead to lower threat levels. I illustrate these results with two examples. The first example in Figure 2.3 shows how changes in controllability affect the optimal threat level.[5] I consider two scenarios, one in the left column and one in the right column. The only difference between the two scenarios is a change in the baseline

[5]This example uses $q[e, \alpha] = \alpha * e$ and $c[e] = \frac{\beta}{2}e^2$. Values for the exogenous parameters are: $\alpha = .65$ (full line) or .85 (dashed line), $\beta = 3$, $\gamma = 0$ (left column) or .1 (right column), $w = .5$, $b_H = 1$, $b_L = .75$, $\delta = .9$, $U^O = 1$, $S^O = 2$, $Q_L = 0$, and $\Delta Q = 3.5$.

probability of high value or the easiness of the task (γ). This is a shift in the intercept of $\gamma + q[e, \alpha]$, see row one. For each scenario I show the effect of increasing the level of controllability. In the figure the full line represents low controllability and the dashed line high controllability. In both scenarios higher controllability leads to more effort for any level of threat (proposition 2). As can be seen in the second row, the dashed line is above the full line. The third row shows how total surplus changes as a function of the threat level. The optimal threat level is where total surplus peaks. In the first scenario (left column) the peak of high controllability is to the left of the peak of low controllability. This is illustrated in more detail in the last row, which shows the first order condition for total surplus. The peaks are exactly at those levels of p where the first order condition crosses the horizontal axis. In the first scenario, the optimal threat level for high controllability is around 14% and for low controllability it is around 16%. The situation is reversed in the second scenario. The peak of total surplus of high controllability is to the right of that of low controllability (row 3). The last row shows that the optimal threat level is about 6% for low controllability and about 10% for high controllability. The relationship between controllability and optimal threat level ($\frac{\partial p^*}{\partial \gamma}$) is thus reversed.

The second example in Figure 2.4 shows that easier tasks may result in lower threat levels.[6] This figure shows just one scenario, where the dashed line is an easier task than the full line. This is represented as a vertical shift of the probability of high value, see the first row. An easier task leads to more effort for any given threat level, as stated in proposition 3. This is illustrated in the second row, where the optimal level of effort for the easier task is above that of the difficult task. The third row shows total surplus as a function of the threat level as the peak of the easy task is to the left of that of the difficult task. As can be seen, the optimal threat level for the easier task is below that of the difficult task. The last rows shows the optimal threat values in more detail. For the easier task it is optimal to set p around 10% and for the difficult task around 13%.

[6]This example uses $q[e, \alpha] = \alpha * e$ and $c[e] = \frac{\beta}{2}e^2$. Values for the exogenous parameters are: $\alpha = .85$, $\beta = 3$, $\gamma = 0$ (full line) or .1 (dashed line), $w = .5$, $b_H = 1$, $b_L = .75$, $\delta = .9$, $U^O = 1$, $S^O = 2$, $Q_L = 0$, and $\Delta Q = 5$.

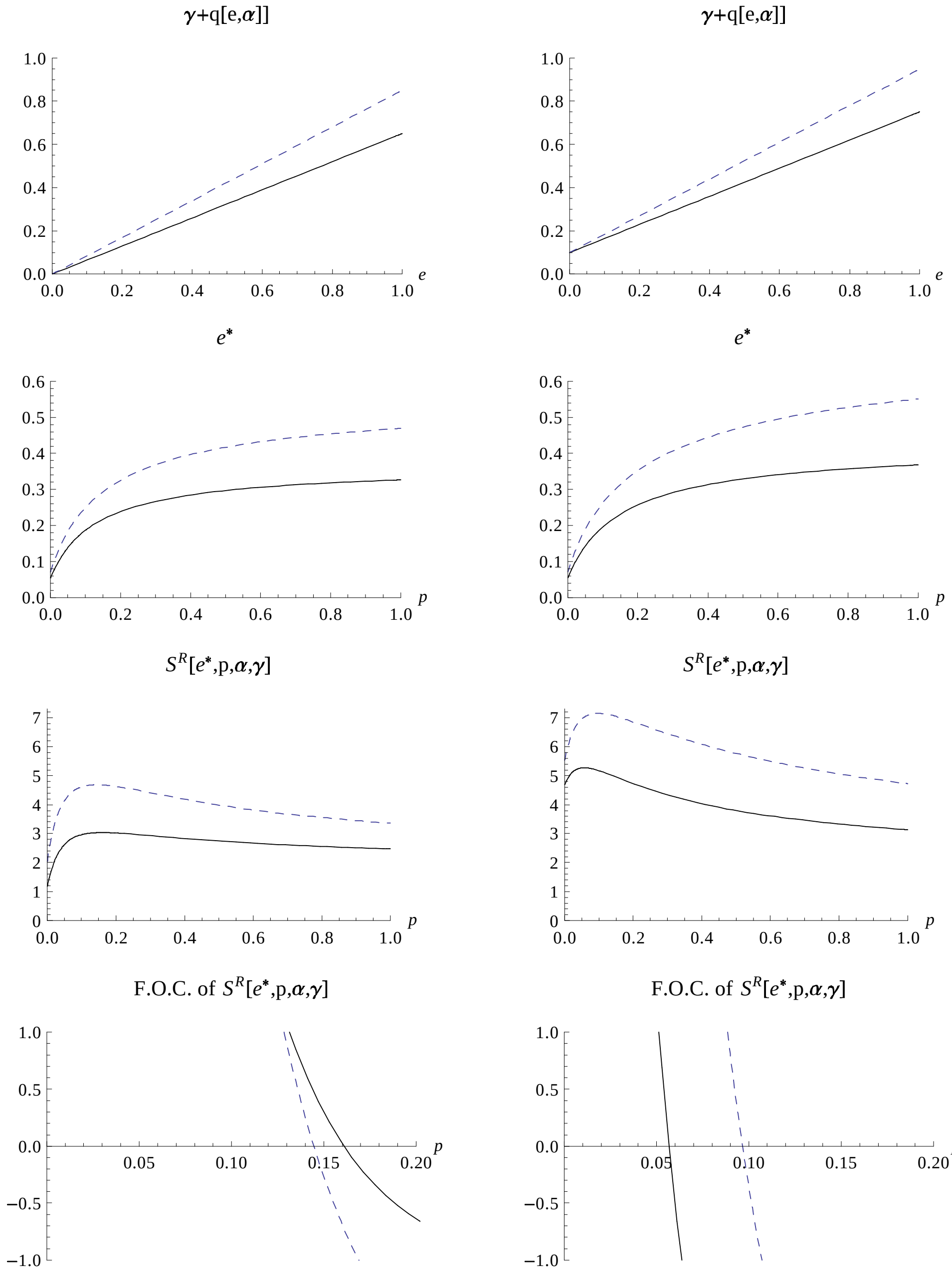

Figure 2.3. Optimal threat level decreases in controllability (α; full line represents low controllability and dashed line high controllability) if $\gamma = 0$ (left column) and increases if $\gamma = .1$ (right column)

Hence, in this scenario the optimal threat level decreases with the easiness of the task $(\frac{\partial p^*}{\partial \gamma})$.

2.6. Discussion

Theories of the firm build on the premise that integration is an important instrument to align incentives. While some theories of the firm experienced closer empirical

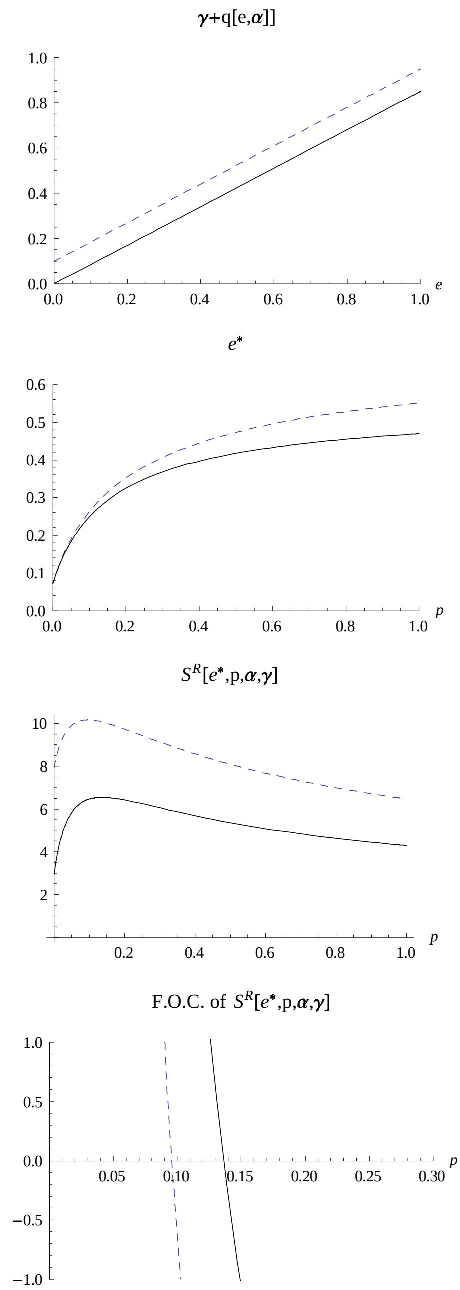

Figure 2.4. Optimal threat level may decrease in easyness of the task (γ; full line represents a difficult task and dashed line an easy task)

scrutiny than others, most empirical studies investigate the decision to integrate (or a closely related decision). However, little research directly explores the difference in incentive alignment between integration and non-integration to verify if integration has greater incentive alignment and how this alignment is actually achieved.

In this chapter I report on a study that compares similar relationships under integration and non-integration. The surprising finding is that, contrary to theory, the degree of cooperation is often greater under non-integration than integration. Non-integration is often linked to greater incentive alignment because the continuation of the relationship is dependent on the performance of the parties involved. In contrast, under integration the continuation of the relationship is more or less guaranteed and only weakly, if at all, linked to performance. Because performance is a stronger decision criteria under non-integration than integration, incentive alignment can be greater externally than internally. In a formal model in the second part of this chapter I provide proof that for a very generic set of relationships a stronger threat of termination in the event of low performance indeed leads to more cooperation (i.e. effort in the model) in the relationship. This supports the findings from the fieldwork.

These findings open up a new interesting debate about the optimal integration decision. If non-integration leads to more cooperation, when would one choose to integrate? The formal model provides some traction on this problem. The optimal threat level (i.e. the probability with which a relationship is terminated if performance is low) depends on the termination effect and the incentive effect. Increasing the threat level results in a higher probability of the relationship being terminated (holding everything else, and in particular performance, constant). If a relationship is more valuable than any alternative, then setting a high threat level can be value destroying. On the other hand, the threat level also provides parties a strong incentive to perform better. A higher threat level is equivalent to a larger stick. If a higher threat level leads to higher performance, then increasing the threat level can be value enhancing. Integration will be preferred if these opposing effects cancel out for low values of threat levels. Non-integration will be preferred if these opposing effects cancel out for high values of threat levels.

Through the model I explore how characteristics of the task influence the optimal threat level. In particular, I focus on two aspects: easiness and controllability. Easiness refers to the extent to which effort is required for a task to be successfully completed. Controllability indicates the extent to which parties' efforts influence the performance of the task. It turns out that without restriction on functional forms, the effects of easiness and controllability on the incentive and termination effect are indeterminate. If easiness and controllability are taken as indicators of technological uncertainty of the task or production process, then this model leads to an intriguing prediction: technological uncertainty need not lead to integration.

Two recent meta-analyses of empirical transaction cost economics research provide some interesting evidence on the association between technological uncertainty and integration. David and Han (2004) report on 63 empirical papers in which 28 tests were provided on the relationship between technological uncertainty and the degree of (vertical) integration. Of these tests, 4 (14%) showed a positive correlation, 6 (21%) a negative correlation, and the remaining an insignificant correlation. Geyskens et al. (2006) analyze 200 papers in which 7 correlations are reported between technological uncertainty and hierarchical governance. Hierarchical governance is operationalized as make versus buy (or integration versus non-integration in the language of this chapter).[7] They find that technological uncertainty is significantly negatively correlated with hierarchical governance. Unfortunately, neither meta-analysis indicates the measures of technological uncertainty that are associated with these results. As such, it is not possible to map the operationalizations of technological uncertainty on easiness and controllability.

2.7. Future Research Directions

This chapter provides the beginnings of a new theory of the firm. The foundations are threefold. First, I empirically derive a key difference between integration and non-integration: the threat of relationship termination is much lower in internal than external vertical relationships. Prior theories of the firm rely primarily on assumptions derived from theorizing rather than from fieldwork. As a consequence, empirical reality may not only be more complicated than the theoretical assumptions, but actually be in contradiction with them (as some of my findings illustrate). Second, I find empirically and show formally how this difference in threat level translates into greater incentive

[7]Even though Geyskens et al. (2006) study more papers, the number of correlations or tests of technological uncertainty is lower than in David and Han (2004). This is because the number of correlations of Geyskens et al. (2006) only reflects the studies that look at the make-buy decision, while the number of tests of David and Han (2004) also includes studies that look at the degree of integration. Not all papers in David and Han (2004) are included in Geyskens et al. (2006).

alignment externally than internally. This is in contrast to most theories of the firm, where integration is assumed to lead to greater incentive alignment. Third, I clearly identify the relative benefits and costs of integration versus non-integration: the incentive versus termination effects. Vertical integration provides a more stable environment beneficial for valuable relationships at the costs of muted incentives. Eventually, any theory of the firm should provide an integrated account of the benefits and costs of integration (Grossman and Hart, 1986; Gibbons, 2005).

The main area for future research is to determine how and when these benefits and costs of integration vary, and as a consequence what determines the boundaries of the firm. Only if these steps are taken, then this theory can develop into a theory of the firm. Two complementary approaches can be taken: a formal and an empirical. First, along the lines of this chapter, a formal approach could uncover parameters that either univocally increase or decrease the strength of the incentive effect relative to the termination effect. The technological uncertainty parameters investigated in this chapter influence the incentive and termination effect, yet it is hard to predict the relative moment of these effects. Several ways are possible the resolve the indeterminacy. One is to explore the usefulness of differential equation calculus to investigate the optimal threat level, as this level is described by a differential equation (see 2.6). Another is to resolve the indeterminacy by putting more restrictions on the functional forms. Possibly, a model with specific functional forms could lead to closed form solutions and illustrate the intuition behind the model. Finally, another way forward is to reshape the model. For example, instead of modelling quality as either low or high, we could model quality as a continuous construct. A relationship would then be terminated if (probabilistic) quality is below a certain threshold. In line with my empirical findings, this threshold would be lower internally than externally.

Second, an empirical approach could reveal if integration decisions correlate with incentive and termination effects. One would expect that vertical integration is chosen when termination effects are high and incentive effects are low. That is when the potential loss of terminating the relationship is high (termination effect high) and when more effort brings little additional value to the relationship (incentive effect is low). Non integration is expected when the opposite holds, i.e. when termination effects are low and incentive effects are high. The empirical challenge is to find reliable predictors for the termination effect and the incentive effect. For example, one expects the termination effect to be stronger the higher the value of the relationship (relative to next best alternative). This is more likely the case with complementary assets. Together these steps could build on the evidence and arguments provided in this chapter and lead to a new theory of the firm.

2.8. Conclusion

The prospect of future business is an important motivator for exchange partners in vertical relationships. Paradoxically, this shadow of the future only provides incentive alignment if that joint future is somewhat uncertain and has to be earned. To the extent that within firms the continuation of a relationship is more guaranteed then between firms, incentive alignment based on the expectation of future business is higher externally than internally. In my empirical setting, I find that the difference in incentive alignment can be such that cooperation is higher between than within firms. While a very high guarantee of a future relationship may not be optimal, a very low guarantee may also not be optimal. In a formal model, I show that a low continuation probability runs the risk of terminating a relationship early that could have been valuable over the long run.

CHAPTER 3

Vertical Integration and Trust

3.1. Introduction

Trust in vertical relationships is important for conducting economic exchanges (Arrow, 1974). The study of vertical relationships and the role of trust in them has come to be dominated by two widely cited, and somewhat contradictory, theoretical perspectives. The first, economic sociology, argues that economic exchanges are best understood in terms of how they are embedded in social relationships (Granovetter, 1985). An important consequence of these ongoing social relationships is trust, which in turn facilitates the efficient exchange of goods and services (Macaulay, 1963; Gulati, 1995; Uzzi, 1997). According to this stream of research, in order to understand the performance of vertical relationships the focus of analysis should be on informal mechanisms like trust rather than on formal governance modes, like markets and hierarchies, and the contracts or hierarchical structures used within them. In contrast, transaction cost economics emphasizes the importance of studying the formal governance modes used to organize economic exchanges with trust relegated to a background phenomenon (Williamson, 1975, 1985). Nonetheless trust, or more appropriately the lack thereof, plays an important role as a necessary assumption to claim the effectiveness of formal governance modes. As Williamson (1993, p. 97) puts it, "[b]ut for opportunism, most forms of complex contracting and hierarchy vanish." In this theory, the role of hierarchical governance structures is to prevent and limit the detrimental consequences of opportunistic behavior.

Despite the theoretical importance, we know little about if and how firm boundaries affect trust within exchange relationships. For instance, a number of studies show that market transactions can be associated with high levels of trust (Zaheer and Venkatraman, 1995; Uzzi, 1997; Sako and Helper, 1998). However, they do not systematically compare such external transactions with internal transactions, i.e. with transactions between partners of the same firm. This makes it difficult to fully engage in a dialogue with the transaction cost perspective, which emphasizes the differences in exchange relationships across governance modes, not the absolute nature of exchanges in different governance modes (Williamson, 1985). Put differently, the economic sociology approach has focused on trust in market relationships in an effort to show that there can be more of it than in stylized, atomistic markets, but has not shown that these levels of trust are higher than in hierarchies. However, it is also true that in much of transaction cost research, the manner in which contractual structures affect the restraint of opportunism is asserted rather than empirically verified. The result is that apart from the general sense that the social and contractual perspectives on exchange are competing views, we know little about the manner in which these aspects of exchange relate to each other.

In this study, I examine how firm boundaries affect trust within exchange relationships. Specifically, I investigate the effect of vertical integration on trust between exchange partners and the conditions under which this effect is stronger or weaker. I build on the premise that in an exchange relationship one cannot observe a partner's trustworthiness directly, but one needs to rely instead on cues and information from the other's behavior to make a trust assessment. I argue that vertical integration affects both the behavior in the relationship and how such behavior is interpreted when updating beliefs about the other's trustworthiness. From this, I predict when the effect of vertical integration on trust should be weaker or stronger.[1]

The empirical setting is vertical (procurement) relationships in the automobile manufacturing industry. Vertical relationships have been the favorite testing ground for both transaction cost as well as embeddedness scholars (Monteverde and Teece, 1982*a*; Walker and Weber, 1984; Masten et al., 1991; Uzzi, 1997). Using survey data on the procurement relationships of Ford and Chrysler, I first assess if the extent to which trust between a buying and supplying unit differs when these units belong to the same

[1]We do not directly focus on the effects of pre-existing trust on the choice of governance mode. For such analyses see Gulati and Nickerson (2008) and Puranam and Vanneste (2009).

firm ("internal") or belong to different firms ("external"). I then examine the conditions under which the difference in trust within versus between firms becomes weaker or stronger. I find that the average level of trust is similar in internal and external relationships. I also find that the effect of vertical integration on trust becomes greater with longer (i.e. duration of prior relationship) and more intensive interactions (i.e. employees working at both units), and under high asset specificity.

Professor Ranjay Gulati with the support of Professor Paul Lawrence, both from Harvard Business School, collected the data in the mid nineties. He very generously gave me access to the data and allowed for its use in this study. The rich data has been the source for three other studies that investigate some aspect of trust in vertical relationships. All differ from mine in important ways. Gulati and Sytch (2007) and Gulati and Sytch (2008) focus exclusively on external vertical relationships and thus do not speak to differences in trust levels across procurement modes. Gulati and Nickerson (2008) use trust as an independent variable and study how it influences exchange performance. I use trust as a dependent variable. To facilitate comparison, I will use the same measures for shared constructs.

3.2. Theory

3.2.1. Trust in vertical relationships

Trust has been studied across several disciplines including sociology, psychology, and economics. Despite their different intellectual origins, these theoretical perspectives have similar conceptions of trust (Rousseau et al., 1998). In this paper, I use a definition of trust that captures this consensus: "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" (Mayer et al., 1995, p. 712). Trust between units in a vertical relationship is the extent of trust placed in the partner unit by members of the focal unit (Zaheer et al., 1998).

Risk is a necessary condition for trust to be meaningful (Bradach and Eccles, 1989; Mayer et al., 1995; Bhattacharya et al., 1998; Rousseau et al., 1998). Given that contracts are incomplete (Williamson, 1975), some risk is always present in market transactions. Risk in market transactions can take many forms: suppliers may deliver inferior products that are difficult to distinguish from high-quality products, proprietary information might be leaked and used in other relationships, and loopholes in contracts could be exploited. Likewise, risk in internal procurement is by no means absent because the "efficacy of hierarchical power within organizations" is restricted (Granovetter, 1985). For example, internal units may misrepresent their true cost structure to other units and senior management in order to obtain more beneficial transfer prices (Eccles, 1985), internal product and service delivery may be delayed because priority is given to external parties, or conflicts may arise when competing for the same limited resources (e.g. budgets for investments).

While trust alleviates the fear of opportunistic behavior and facilitates cooperation, trust is not a necessary condition for cooperation (Mayer et al., 1995). Exchange partners may simply cooperate because it is in their best interests to do so. In chapter 2 for example, I argued that the promise of future business gives exchange partners a strong incentive to behave cooperatively. The trust literature has widely recognized the difference between expecting a partner to behave cooperatively because the other is intrinsically motivated or because the other is strongly incentivized. For example, building on Shapiro et al. (1992), Lewicki and Bunker (1996) distinguish between knowledge-based, identification-based, and calculus-based trust. The first two (knowledge and identification) coincide with intrinsic motivation, while the last (calculus) relates to extrinsic incentives.

Knowledge-based trust relies on information and develops over time. It is built on the premise that a partner's level of trustworthiness is difficult to assess directly. Repeated interactions however provide exchange partners opportunities for trust assessment, as they observe each other's actions, behaviors, or the outcomes of those

(Lindskold, 1978). Prior trusting behaviors lead to increased willingness to be vulnerable in the future, leading to increased trust (Boyle and Bonacich, 1970; Mayer et al., 1995). The simplified image of knowledge-based trust is one in which there are two types of exchange partners: those that are trustworthy and those that are not. It is difficult to tell these types apart. Over time and from observed actions and outcomes one can learn which type one is dealing with. Only if the other is from the good type will an exchange partner be willing to accept significant vulnerability.

Identification-based trust is based on the internalization of other's preferences. Identification is "the perception of oneness with a group of persons" (Ashforth and Mael, 1989, p. 20). It leads to increased cooperation and positive evaluations of the group (Turner, 1982, 1984). An important driver of identification is relationship duration (Dutton et al., 1994). For example, Bhattacharya et al. (1995) find that the number of membership years is positively correlated to organizational identification. This effects holds even for members who have left the organization (Mael and Ashforth, 1992).

Identification leads to the internalization of other's preferences into one's own (Shapiro et al., 1992). As a result, parties' goals become better aligned. Opportunistic behavior is less likely, simply because such behavior would go against the preferences of the perpetrator. In support of this argument, Kramer and Brewer (1984.) find through a series of experiments that groups with stronger identification are more willing to forego individual returns for the sake of the common good in situations of declining and scarce resource pools. Thus, identification leads to more trustworthy behavior.

The stylistic version of identification-based trust is as follows. People behave in accordance with their preferences. When interacting repeatedly, people identify with each other and with time preferences become more aligned. Given better preference alignment, it is less likely that one will be taken advantage off, leading to increased trust.

Calculus-based trust is based on the calculus of the immediate and long-term benefits of behaving cooperatively and comparing those with the immediate and long-term benefits of behaving uncooperatively (Axelrod, 1984; Lewicki and Bunker, 1996). Exchange partners influence these benefits as they can reward or punish each other's behavior in the future. For example if a supplier behaves cooperatively, the buyer is more likely to reciprocate than if the supplier had not (Ring and Van De Ven, 1994). On the other hand if a supplier behaves opportunistically, the buyer may retaliate or punish the supplier (Heide and Miner, 1992). Thus, the future casts a shadow on present behavior. Calculus-based "trust" is the central mechanism in chapter 2.

Trust is not the same as expected cooperation, as cooperation could merely be anticipated due to the presence of incentives and contracts even in the absence of trust. For that reason many would argue that trust refers only to those expectations based on the other party's goodwill or benign intent (Yamagishi and Yamagishi, 1994; Mayer et al., 1995). Hence, calculus-based "trust" would be a "contradiction in terms." (Williamson, 1993, p. 463). In this paper, I follow the trust definition of Mayer et al. (1995) and exclude calculus-based sources from trust. The reason is that under strong external incentives trustworthy and untrustworthy partners act alike and thus risk is absent. Given that risk is a necessary condition for trust (see above), I do not include calculus-based sources into trust. Of course, it is difficult to disentangle whether a party cooperated because of strong intrinsic motivation or because of powerful external incentives. This attribution problem is central to this paper.

Because a partner's level of trustworthiness is difficult to assess directly, exchange partners have to rely on alternative information to infer the other's level of trustworthiness. Ongoing exchange relationships are an important source of such information. In exchange relationships, partners observe each other's actions, behavior, or the outcomes of these. These cues provide partners opportunities for trust assessment (Lindskold, 1978). Partners use these cues to revise their trust assessment of the other upward or downward (Boyle and Bonacich, 1970; Mayer et al., 1995). For example, prior trusting behaviors lead to increased willingness to be vulnerable in the future and hence to higher trust. Similarly, if negative actions or outcomes are partly attributed to the exchange partner, then trust in that exchange partner will decrease. Over time and from observed actions and outcomes, one can learn whether the other is trustworthy. Only if the other is trustworthy will an exchange partner be willing to accept significant vulnerability.

3.2.2. Vertical integration and trustworthy behavior

Opportunism is a key behavioral assumption in transaction cost economics (Williamson, 1975, 1985). It is stronger than mere self-interest and refers to "the incomplete or distorted disclosure of information, especially to calculated efforts to mislead, distort, disguise, obfuscate, or otherwise confuse" Williamson (1985, p. 47). Given opportunism, safeguards are needed to curb its negative consequences on economic exchanges. According to TCE, the raison d'être of firms is providing these safeguards.

Williamson (1975, 1991) argues that the tendency to behave opportunistically is lower in firms than in markets. This difference is due to muted incentives and administrative controls. First, internal divisions have less incentive to behave opportunistically, because they "do not ordinarily have pre-emptive claims on their respective profit streams" (Williamson, 1975, p. 29). External units are compensated more on the basis of pre-specified prices relative to internal units, who tend to be rewarded on the basis of cost-plus agreements. An external unit's incentive is the difference between price and costs. To the extent that an external party can keep the rewards of opportunistic behavior, such behavior will be more prevalent. Second, to manage their internal exchange a firm makes use of administrative controls that are hard to replicate to a similar extent between firms. Such controls, including monitoring, penalties, and career rewards, limit opportunistic behavior. These mechanisms together suggest that exchange partners in firms behave less opportunistically than exchange partners in markets. Therefore, the willingness to be vulnerable should be higher internally than externally. In other words, trust should be higher within firms than between firms.

At the same time, because of the muted incentives and administrative controls, internal units face less pressure to perform than external units. This consequence of low-powered incentives has been referred to as "bureaucracy costs" (Williamson, 1985).

If such bureaucracy costs imply that exchange partners put in less effort, respond slower to each other's requests, or behave less willingly in internal than external relationships, then it will negatively affect the trust assessment internally compared to externally. The joint outcome of these two opposing effects – weaker incentives to behave opportunistically, but also weaker incentives to act cooperatively – is not clear. Hence, it is hard to predict whether the effect of vertical integration on trust is positive or negative. However, I can exploit differences in situations to predict under which conditions this effect is greater (but not necessarily positive) relative to other conditions.

One of the core arguments of transaction cost economics is that vertical integration is preferred when asset specificity is high and non-integration is preferred when asset specificity is low (Williamson, 1985). This argument has received broad empirical support (David and Han, 2004; Geyskens et al., 2006). Under high asset specificity the potential scope for opportunism is large, because assets cannot be redeployed in alternative relationships without substantial loss in value. This provides the opportunity for an exchange partner to hold-up the other. Because under non-integration the tendency to exploit such opportunities is larger, vertical integration is preferred if such opportunities are numerous. Under low asset specificity, the risk of opportunism is low because exchange partners can use their (valuable) assets for multiple partners. In this situation, non-integration is preferred over vertical integration because non-integration provides strong incentives to perform without the risk of hold-up.

Because trust assessment is based on the observed behavior and outcomes in a relationship, more productive behavior and better outcomes should lead to more trust everything else being equal. Because under low buyer asset specificity an external supplier will do better than an internal supplier and under high buyer asset specificity the opposite holds, I predict that:

Hypothesis 1: Buyer asset specificity positively moderates the association of vertical integration on trust in the supplier.

3.2.3. Vertical integration and the attribution of trustworthy behavior

While vertical integration affects behavior in exchange relationships, it also affects how behavior is interpreted when updating trust beliefs. I discussed the first aspect above, I discuss the second below. The argument is based on the following two premises. First, incentive intensity is higher in external than internal relationships. Second, higher incentive intensity reduces the attribution of trustworthiness because actions are seen more as driven by incentives rather than noble motives. From this it follows that information generation mechanisms (e.g. prior relationships, and employees at each other's facilities) should have a greater effect on trust internally than externally. I discuss the different elements below.

First, incentives are stronger in market than firm relationships. Williamson (1985) argues that vertical integration comes with the unavoidable consequence of muted incentives. Using a thought experiment of one big firm replicating market transactions for all activities "save those for which the expected net gains from intervention could be projected", he suggests that selective intervention by the owner(s) of the big firm management can never be as efficient as market transactions. If the owner of the big firm wants to replicate asset-ownership like strong incentives, the owner can only do so at additional cost of monitoring. Because of the high monitoring costs that would have to be incurred to provide strong incentives, incentives are bound to be weaker internally than externally.

Using a formal repeated games framework, Baker et al. (2002) reach the same conclusion that optimal incentives are weaker under vertical integration than under non-integration. The reason is that high-powered incentives (or bigger bonuses) create bigger reneging temptations under vertical integration than under non-integration. In this framework, a downstream party reneges if it refuses to pay a bonus that was promised to an upstream party. A downstream party has a greater temptation not to pay a promised bonus to an integrated than to a non-integrated upstream party, because in their setting upon reneging a downstream party will still get the produced good from the integrated but not from the non-integrated party.

Chapter 2 suggests an additional mechanism for why incentives are stronger in market than firm relationships. That chapter provides evidence that internal suppliers have a lower chance of getting fired in the event of poor performance. Often social norms and formal company policy dictate that relationships should be continued within firms under conditions where they would not be between firms. Because of a lower threat of dismissal, internal suppliers face weaker incentives than external suppliers. Together, these mechanisms suggest that incentive intensity is stronger between firms than within firms.

Second, higher incentive intensity hinders the development of trust between exchange partners. When assessing an exchange partner's trustworthiness, cues from prior actions are an important source of information. Prior cooperation tends to increase the willingness to be vulnerable, yet such cooperation needs to be seen as arising from a partner's integrity or benevolence (Mayer et al., 1995). Cooperation is not sufficient for trust to emerge. The presence of strong incentives limits the attribution of prior cooperation to a partner's disposition, but instead makes it more likely that actions are seen as a result of extrinsic rewards (Molm et al., 2000; Malhotra and Murnighan, 2002). If a party cooperates without any incentives, then it must be because that party is trustworthy. If a party cooperates under strong incentives, then that party may or may not be trustworthy. In the last instance trustworthy and untrustworthy parties would behave alike or consensus of actions is high, which makes situational attributions more likely (Kelley, 1967).

In an experimental setting, Malhotra and Murnighan (2002) showed this effect through the use of non-binding and binding contracts. Non-binding contracts were mere promises to cooperate in a two player trust game, while under binding contracts cooperation was guaranteed. The finding was that the removal of binding contracts led to a significant drop in the willingness to be vulnerable in the trust game, while the removal of non-bonding contracts had less impact on the continued willingness to be vulnerable.

Thick information arising out of the relationship is crucial when updating beliefs about a partner's trustworthiness (Gulati, 1995). The level of incentive intensity will influence this updating process. Following the arguments above, I expect information from the relationship to be interpreted more favorably under vertical integration than under non-integration. In the empirical section I focus on two important generators of information: temporal and spatial connections.

There is a long history in the trust literature that links trust formation with repeated interactions because these allow for the observation and interpretation of one's exchange partner's actions over a prolonged period (Boyle and Bonacich, 1970; Lindskold, 1978; Anderson and Weitz, 1989; Parkhe, 1993; Gulati, 1995; Zaheer et al., 1998; Dyer and Chu, 2000). Because these actions are interpreted more favorably under vertical integration than under non-integration, I expect:

Hypothesis 2: Relationship duration positively moderates the association of vertical integration on trust.

Just as more information about a partner is obtained the longer one interacts, more information can also be obtained through directly observing the partner (Doz et al., 2001). Direct observation occurs when partners work at each other's facilities for some or most of their time. Because information from such employee co-location is viewed more favorably under non-integration, I expect:

Hypothesis 3: Employee co-location positively moderates the association of vertical integration on trust.

3.3. Methods

3.3.1. Sample

I use a 1995 survey of lead buyers of various components at Ford Motor Company and at Chrysler Corporation. Professors Ranjay Gulati and Paul Lawrence designed and implemented the survey. Below I refer to them as "the researchers" and describe how they collected the data. Based on a previous study of the automobile sector (Monteverde and Teece, 1982*b*) and their discussions with informants in the automobile industry, the researchers developed a list of 120 components that go into most automobiles. They verified the comprehensiveness of this list with several executives in the industry and also through a comparison with component lists used by the firms to monitor their own parts quality. In-depth interviews with managers at both companies preceded the design of the questionnaire and influenced many of the items included. The researchers conducted a total of 37 interviews (16 at Chrysler and 21 at Ford). They spoke with managers responsible for both external and internal sourcing. These included individuals in purchasing, quality control, platform management, and engineering operations. The interviews were exploratory and open ended and focused on the characteristics of each individual's particular component, the type of sourcing arrangement and supplier used, its relative performance, the pros and cons of alternative sourcing arrangements for that component, and key constructs for this study.

They designed the survey instrument on the basis of these interviews and items from prior studies on vertical relationships. They thoroughly pretested the survey with several groups of senior managers at the participating companies to clarify ambiguities and examine the face validity of our measures. Three groups of five executives each at the two companies went through the survey together to identify questions that were unclear or subject to multiple interpretations, revealed sensitive information, were difficult to answer, or were subject to social desirability bias. The researchers incorporated the detailed feedback from these groups and then sought additional input from them on the revised instrument to make additional changes. To reduce response bias, they also scattered questions measuring each construct across the survey and used multiple response formats.

For each component, senior managers at Ford and Chrysler provided them with the names of individuals with oversight over the sourcing of that component. They mailed our survey to these individuals. Each survey respondent provided data on the component he or she was in charge of sourcing, as well as data on the two largest suppliers (or one, if only one existed) for that component. We ensured that each survey respondent was the expert for a given component by verifying his or her expert status with the controller's office in each company. Their cover letter to respondents indicated that they had been identified as an expert on the acquisition of a given component and asked for the return of the uncompleted survey and a nomination of an expert if this was not the case.

Survey implementation took several standard steps to ensure a good response rate. Sixty-four executives responded from Ford, and 67 executives responded from Chrysler, representing response rates of 53 percent and 56 percent respectively, and a overall response rate of 55 percent. They obtained usable data for this study on 241 procurement relationships, though data limitations reduced the effective number of observations for some analyses. They checked for non-response bias by comparing the characteristics of the components for which we received responses against those for which we did not receive a response. For each company, the researchers assessed whether the components in the sample differed significantly from those which were not in the sample, on two key characteristics of components identified in prior research: type of sourcing and engineering complexity. They relied on the ratings of Monteverde and Teece (1982*a*), the primary types of sourcing of all components in automobiles, and ratings of their engineering complexity as a basis for this comparison. They used the Kolmogorov–Smirnov two-sample test to assess the possibility of differences in the distribution of components in and outside the sample across these two variables (Sidney, 1956). The results of this test indicate that sample selection bias is not an issue with these data.

For each of the 241 procurement relationships in the sample respondents indicated whether it was a purchasing arrangement with an internal division of their company (internal procurement) or a purchasing arrangement with an external supplier (market procurement). Of the 241 exchanges in the sample, 30 were organized as internal procurement and 211 were organized as market procurement.

3.3.2. Measures

Measures in this study follow whenever possible prior work on the same dataset, e.g. Gulati et al. (2005), Gulati and Sytch (2007, 2008), and Gulati and Nickerson (2008).

3.3.2.1. Dependent variable. I measure *trust* through the following six items derived from prior literature (Zaheer et al., 1998; Gulati and Sytch, 2007, 2008): 1) you trust this supplier to treat you fairly, 2) you trust that confidential / proprietary information shared with this supplier will be kept strictly confidential, 3) this supplier has always been even handed in its negotiation with your company, 4) this supplier may use opportunities that arise to profit at your expense (reverse coded), 5) based on past experience, you cannot with complete confidence rely on this supplier to keep promises made to you (reverse coded), and 6) you are hesitant to transact with this supplier when the specifications are vague (reverse coded). All items are measured on a 7-point Likert with options ranging from 1 = strongly disagree to 7 = strongly agree. Exploratory factor analysis revealed only one factor with eigenvalue greater than one (2.90), on which all items loaded. I use the factor score. Cronbach's alpha for the six items is 0.85.

3.3.2.2. Independent variables. *Vertical integration* is a dummy variable that is one if the purchasing arrangement is between organizational units of the same firm and zero if the arrangement is between units of different firms. *Buyer asset specificity* is measured as the respondent's agreement with the following statement (7-point Likert scale with options ranging from 1 = strongly disagree to 7 = strongly agree): Your company has made significant investments in terms of tooling and equipment which are specific to your relationship with this supplier (Williamson, 1985; Gulati et al., 2005; Gulati and Nickerson, 2008). *Relationship duration* is measured as the natural logarithm of the number of years the commodity has been purchased from the supplier (Gulati et al., 2005; Gulati and Sytch, 2007; Gulati and Nickerson, 2008). *Employee co-location* is assessed through two items capturing the number of a) buyer employees and b) supplier employees who work at least 25% of their time at the partner's facilities. The measure is the natural logarithm of the sum of the two items.

3.3.2.3. Control variables. I include several control variables that might simultaneously impact the dependent and independent variables. First, I control for *supplier asset specificity* as important transaction characteristics (Williamson, 1985; Gulati et al., 2005; Gulati and Nickerson, 2008). This variable was measured as the respondent's agreement with the following statement (7-point Likert scale with options ranging from 1 = strongly disagree to 7 = strongly agree): This supplier has made significant investments in terms of equipment, facilities, and engineering designed specifically to meet our supply requirements for this commodity. Second, I control for the *technological ability* of the supplier as ability is an important component of trust (Mayer et al., 1995). I used the following item "This supplier has proprietary technology that gives it significant advantage over other producers" (with a 7-point Likert scale with options ranging from 1 = strongly disagree to 7 = strongly agree). Finally, I included a dummy *Ford* to control for differences between Ford and Chrysler. To mitigate concerns about respondent bias, I include a measure of *buyer history* to control for the history of the respondent's interaction with the supplier (Kumar et al., 1993; Gulati et al., 2005). This is measured as the natural logarithm of the number of months the respondent has been personally associated with the supplier.

3.3.3. Analysis technique

I am interested in the treatment effect of vertical integration on trust and its moderators. A treatment effect is the difference between the results observed under the treatment and what would have happened without the treatment (Rubin, 1974). In field data we often encounter non-random assignment to treatment (Shadish et al., 2002), which is the case if the choice to vertically integrate is not random. If some transactions are best organized internally and others externally (Williamson, 1985), then a manager's decision to vertically integrate will not be random. As a consequence, we expect internal and external transactions to be different.

When estimating how much trust differs within versus between firms, we need to eliminate any trust difference due to differences in transactions. If we do not, then any variation in trust can be equally likely ascribed to the specifics of the procurement mode as to the nature of the transaction. While I capture some transactional characteristics through the control variables, others I may not. If these unobserved characteristics are correlated with trust, then ignoring them would lead to biased estimates in OLS.

I use a Heckman correction to control for these unobserved characteristics, which allows us to isolate the treatment from the selection effect (Heckman, 1979). See Hamilton and Nickerson (2003) for a detailed discussion. A model with Heckman correction is estimated in two steps. First, I estimate a probit model of procurement mode. I use the estimates of this model to calculate a non-selection hazard into each mode of procurement for each observation, which takes into account the effect of unobservable variables that influence the procurement mode decision. Second, I use OLS to regress trust on the independent and control variables and the non-selection hazard. By its inclusion, the non-selection hazard controls for any unobservable features of the relationships that might simultaneously affect the procurement mode choice and trust. For identification purposes, I include a measure of employee benefits in the first model and exclude it from the second model. This measure captures the respondent's assessment on a seven point scale of the supplier's *employee benefits* from limited (=1) to generous (=7). Because internal suppliers are more unionized than external suppliers (Klier and Rubenstein, 2008), and because union employees receive more generous (non-contingent) compensation packages employee benefits should be correlated with procurement mode. I have no prior theoretical reason to expect a direct effect of employee benefits on trust, suggesting that employee benefits is a useful auxiliary variable for identification (Hamilton and Nickerson, 2003).

3.4. Results

Figure 3.1 reports the summary statistics and pairwise correlations between variables used in the analysis. Two high correlations stand out: between vertical integration and its interaction with buyer asset specificity (0.98) and its interaction with relationship duration (0.98). While high (but not perfect) correlation between the independent

	Mean	S.D.	Min	Max	1.	2.	3.	4.
1. Trust	0.00	0.92	-3.40	1.70				
2. Vertical integration	0.12	0.33	0	1	-0.09			
3. Buyer asset specificity	4.73	1.74	1	7	-0.05	0.26		
4. Relationship duration	2.47	0.78	0	4.32	-0.12	0.34	0.09	
5. Employee co-location	0.87	1.29	0	7.82	-0.06	0.41	0.17	0.28
6. Buyer asset specificity * Vertical integration	0.73	1.98	0	7	-0.06	0.98	0.29	0.34
7. Relationship duration * Vertical integration	0.34	1.02	0	4.25	-0.05	0.98	0.22	0.39
8. Co-location * Vertical integration	0.24	1.11	0	7.82	-0.02	0.66	0.11	0.22
9. Supplier asset specificity	5.69	1.15	1	7	0.22	0.11	0.29	0.00
10. Technological ability	4.01	1.63	1	7	0.34	-0.09	0.14	-0.02
11. Ford	0.49	0.50	0	1	-0.11	0.21	-0.08	0.14
12. Buyer history	3.06	0.86	0	5.48	-0.10	-0.16	0.04	0.11
13. Employee benefits	4.25	1.22	1	7	0.00	0.37	0.16	0.09

	5.	6.	7.	8.	9.	10.	11.	12.
6. Buyer asset specificity * Vertical integration	0.38							
7. Relationship duration * Vertical integration	0.43	0.97						
8. Collocation * Vertical integration	0.76	0.62	0.67					
9. Supplier asset specificity	0.02	0.13	0.10	0.04				
10. Technological ability	-0.04	-0.06	-0.09	-0.14	0.32			
11. Ford	0.13	0.20	0.20	0.21	-0.12	-0.18		
12. Buyer history	0.02	-0.15	-0.13	-0.12	0.07	0.09	-0.29	
13. Employee benefits	0.14	0.37	0.34	0.19	0.18	0.13	0.10	0.01

Figure 3.1. Pairwise correlations and descriptive statistics[2]

variables does not violate any assumptions of the regression framework and does not create any biases in the estimates (Greene, 2003), I report additional analyses to explore how multicollinearity influences the results. A third high correlation, between these two interaction terms (0.97), is not an issue because these variables do not feature in the same model.

Figure 3.2 gives the probit regression with vertical integration as the dependent variable. While the decision to vertically integrate is not the focus of this paper, I use the estimates of these models to construct Heckman corrections for the trust models. The number of observation is between 201 and 225 and all models provide a good fit ($p < .01$). The auxiliary variable employee benefits is positive and highly significant across all models ($p < .01$). As expected, internal suppliers have more generous employee benefits than external suppliers. In line with transaction cost economics, I find that buyer asset specificity is higher under vertical integration ($p < .01$, model 2), but interestingly supplier asset specificity is not. In the sample, the relationship with the internal suppliers is longer than with the external suppliers ($p < .01$, model 3). More

[2]Absolute correlations greater than 0.13 are significant at 5% level.

	(1)		(2)		(3)		(4)	
Buyer asset specificity			0.42	***	0.43	***	0.36	**
			(0.13)		(0.16)		(0.18)	
Relationship duration					1.32	***	1.01	***
					(0.34)		(0.36)	
Employee co-location							0.24	**
							(0.11)	
Supplier asset specificity	0.17		0.00		-0.11		-0.08	
	(0.14)		(0.16)		(0.19)		(0.22)	
Technological ability	-0.17	**	-0.23	**	-0.41	***	-0.45	**
	(0.09)		(0.10)		(0.15)		(0.18)	
Ford	0.64	**	0.73	**	0.14		0.04	
	(0.30)		(0.32)		(0.42)		(0.47)	
Buyer history	-0.30	*	-0.34	**	-0.52	**	-0.17	
	(0.16)		(0.17)		(0.26)		(0.30)	
Employee benefits	0.67	***	0.72	***	0.83	***	0.75	***
	(0.14)		(0.15)		(0.21)		(0.22)	
Constant	-4.18	***	-5.39	***	-7.65	***	-7.43	***
	(1.04)		(1.23)		(1.62)		(1.79)	
Chi2	50.41	***	65.17	***	78.51	***	65.25	***
N	225		225		213		201	
Df_m	5		6		7		8	

Figure 3.2. Probit of vertical integration[3]

employees of buyer and supplier work at each other's units in internal than external relationships ($p = .03$, model 4).

Figure 3.3 shows OLS regressions of trust. Standard errors are robust to heteroscedasticity and clustered by component type. The number of observations varies between 199 and 241 due to missing observations on some variables. The adjusted R^2 is between 0.15 and 0.21 and all models show a good fit ($p < .01$). Using the predicted probabilities from the probit regressions in Figure 3.2, I calculate the non-selection hazard for each observation and use it as a control for possible endogeneity of vertical integration (Heckman, 1979; Hamilton and Nickerson, 2003). The non-selection hazard is included in the even numbered models. The odd numbered models exclude this additional control.

In the discussion of the results I focus on the odd numbered models without non-selection hazard for three reasons. First, the non-selection hazard is not significant in any model ($p = .40$ in model 2, $p = .97$ in model 4, $p = .46$ in model 6, and $p = .52$ in model 8). The coefficient of the non-selection hazard provides a direct test for the endogeneity of vertical integration in the models (Greene, 2003). Because the

[3]* p < .1; ** p < .05; *** p < .01 in a two-tailed test. Standard errors are in parentheses.
[4]* p < .1; ** p < .05; *** p < .01 in a two-tailed test. Robust standard errors are in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Vertical integration	-0.27	-0.55	-2.26 ***	-2.47 ***	-1.53 **	-1.02	-0.42 **	-0.12	-3.31 ***	-3.41 **
	(0.17)	(0.34)	(0.67)	(0.74)	(0.71)	(1.16)	(0.20)	(0.43)	(1.16)	(1.66)
Buyer asset specificity			0.35 ***	0.40 ***					0.39 **	0.39 *
* Vertical integration			(0.11)	(0.11)					(0.20)	(0.20)
Relationship duration					0.48 **	0.40			0.22	0.26
* Vertical integration					(0.23)	(0.32)			(0.28)	(0.34)
Employee co-location							0.22 *	0.19	0.23 *	0.21 *
* Vertical integration							(0.12)	(0.12)	(0.11)	(0.12)
Buyer asset specificity			-0.08 **	-0.10 ***	-0.08 *	-0.09 **	-0.07	-0.08 *	-0.08 **	-0.09 **
			(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Relationship duration					-0.15 *	-0.20 **	-0.11	-0.15 *	-0.13	-0.16 *
					(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Employee co-location							-0.12	-0.11	-0.11	-0.09
							(0.08)	(0.09)	(0.08)	(0.09)
Supplier asset specificity	0.11 *	0.12 *	0.13 **	0.14 **	0.14 **	0.13 *	0.12 *	0.11 *	0.11	0.12 *
	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Technological ability	0.17 ***	0.18 ***	0.17 ***	0.18 ***	0.18 ***	0.19 ***	0.18 ***	0.20 ***	0.18 ***	0.19 ***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
Ford	-0.14	-0.06	-0.17	-0.13	-0.09	-0.10	-0.02	-0.03	-0.05	-0.05
	(0.14)	(0.16)	(0.14)	(0.15)	(0.15)	(0.15)	(0.15)	(0.16)	(0.16)	(0.16)
Buyer history	-0.20 **	-0.20 **	-0.20 **	-0.18 **	-0.18 *	-0.15	-0.11	-0.10	-0.13	-0.11
	(0.08)	(0.09)	(0.08)	(0.08)	(0.09)	(0.10)	(0.09)	(0.10)	(0.09)	(0.10)
Non-selection hazard		0.19		-0.01		-0.19		-0.17		-0.04
		(0.23)		(0.23)		(0.26)		(0.27)		(0.30)
Constant	-0.60	-0.68	-0.32	-0.36	-0.12	-0.10	-0.33	-0.28	-0.10	-0.15
	(0.45)	(0.45)	(0.43)	(0.43)	(0.48)	(0.45)	(0.48)	(0.45)	(0.50)	(0.46)
F	6.60 ***	6.30 ***	7.83 ***	8.89 ***	5.32 ***	4.82 ***	4.95 ***	4.50 ***	5.27 ***	5.34 ***
N	241	223	241	223	224	211	212	199	212	199
Df_m	5	6	7	8	8	9	9	10	11	12
Adj. R2	0.15	0.17	0.17	0.20	0.18	0.21	0.16	0.19	0.18	0.20

Figure 3.3. Treatment effect model (OLS) of trust[4]

coefficient across different specifications is not significant, I cannot reject the hypothesis that vertical integration is exogenous with respect to the trust formation process. This suggests that I have controlled for the main factors that simultaneously influence trust and the decision to vertically integrate. Second, the inclusion of the non-selection hazard hardly changes the magnitude of the coefficients of interest (vertical integration in model 1 and 2, and the interaction terms with vertical integration in the other models), though significance levels are somewhat influenced. I formally tested whether the inclusion of the non-selection hazard changes any coefficient, not just those of key interest to us. I could not reject the hypothesis that all coefficients were the same with or without non-selection hazard ($p = .46$ for model 1 and 2, $p = .65$ for model 3 and 4, $p = .68$ for model 5 and 6, and $p = .76$ for model 7 and 8). Third, because it is a function of all independent variables (and correlated with vertical integration), the non-selection hazard exacerbates the issue of multicollinearity. From the correlation matrix (Figure 3.1) I know that the main independent variables (especially buyer asset specificity and relationship duration) have a high correlation with their vertical integration interaction effect. This makes it challenging to efficiently attribute variance in trust to the main effect versus the interaction effect. Including a factor that is strongly correlated with both, makes this even harder.

For the effect of vertical integration on trust I turn to model 1. I find that vertical integration is negative but not significant. The average level of trust between exchange partners is not different under vertical integration than non-integration. Of the control variables, supplier asset specificity is positively associated with trust. As expected, buyers have more trust in suppliers with high technological ability. The level of trust in supplier relationships does not systematically differ between Ford and Chrysler. A longer personal history with the supplier is somewhat surprisingly associated with less trust in the supplier, though this variable loses its significance in the full specification (model 7).

While the average effect of vertical integration on trust across all transactions is not statistically different from zero, the effect may be different from zero under certain

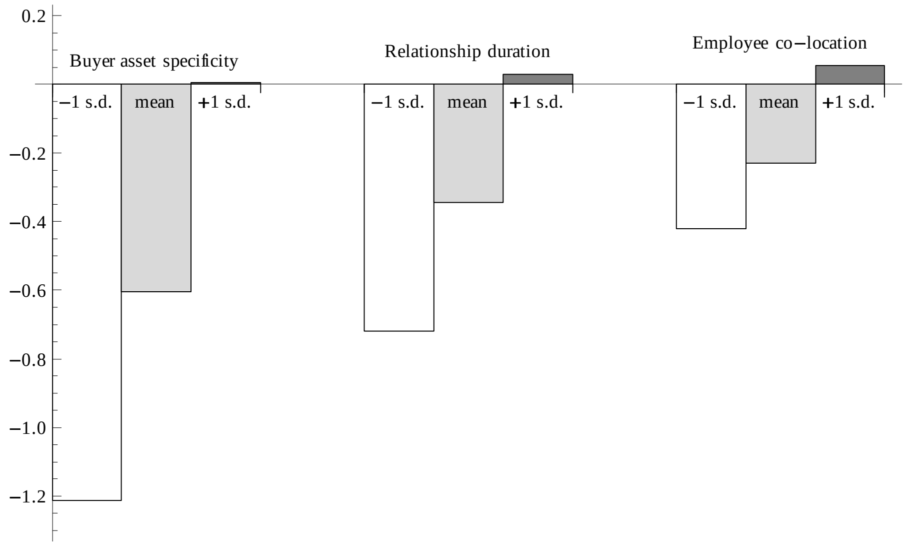

Figure 3.4. The effect of vertical integration on trust (in standard deviations) for various levels of buyer asset specificity, relationship duration, and employee co-location

conditions. In hypothesis 1 I argue that buyer asset specificity positively moderates the effect of vertical integration on trust. To test this hypothesis I include buyer asset specificity and its interaction with vertical integration in model 3. The interaction term is positive and significant, indicating that hypothesis 1 is supported. In this model the effect of vertical integration is β_1 + buyer asset specificity * β_2, where β_1 is the coefficient of the main effect of vertical integration and β_2 is the coefficient of the interaction effect. For buyer asset specificity one standard deviation below the mean the total effect of vertical integration is -1.19 ($p < .01$) and for buyer asset specificity one standard deviation above the mean it is 0.04 ($p = .84$). The standard deviation of trust is about one, hence the coefficients can be interpreted as standard deviations increases or decreases in trust. The average effect of vertical integration as estimated through model 1 masks substantial variation. In model 3 I find that under some settings vertical integration is associated with more than one standard deviations less trust in the supplier than non-integration, while in other settings the effect of vertical integration is positive (though not significantly different from zero). Figure 3.4 shows the effect of vertical integration on trust for various levels of buyer asset specificity.

Hypothesis 2 predicts that relationship duration positively moderates the effect of vertical integration. In model 5 I include relationship duration and its interaction effect with vertical integration. The interaction term is positive and significant ($p < .05$). Hypothesis 2 is supported. In model 5, the effect of vertical integration is β_1 + relationship duration * β_3, where β_1 is the coefficient of the main effect of vertical integration and β_3 is the coefficient of the interaction effect with relationship duration. For a relationship duration one standard deviation below the mean the total effect of vertical integration is -0.72 ($p < .05$) and for one standard deviation above the mean it is 0.03 ($p = .88$). Again, I observe substantial variation in the effect of vertical integration (see Figure 3.4).

In hypothesis 3 I expect that employee co-location positively moderates the effect of vertical integration. I test this through the inclusion of employee co-location and its interaction effect with vertical integration in model 7. The interaction effect is positive and (marginally) significant ($p < .07$). This provides some support for hypothesis 3. In model 7, the effect of vertical integration is β_1 + relationship duration * β_5, where β_1 is the coefficient of the main effect of vertical integration and β_5 is the coefficient of the interaction effect with employee co-location. With employee co-location one standard deviation below the mean the total effect of vertical integration is -0.42 ($p = .04$) and for the number of employees co-located one standard deviation below the sample mean it is 0.06 ($p = .78$), see Figure 3.4.

In model 9 I present the full model with all three interaction effects. The coefficients are roughly similar to those of the models with a single interaction effect though significance levels are slightly lower: the interaction effect of vertical integration with buyer asset specificity ($p < .05$), with relationship duration ($p = .43$), and with employee co-location ($p = .05$). One explanation for the lower significance levels is multicollinearity, because the interaction effects are strongly correlated with each other and with vertical integration. Estimating three slopes for the relationship between vertical integration and trust may be asking too much of the data.

3.4.1. Additional analyses

The interaction effects of buyer asset specificity with vertical integration and relationship duration with vertical integration have variance inflation factors greater than 10, indicative of multicollinearity. Multicollinearity does not affect the unbiasedness of the estimates, but makes it harder to obtain efficient estimates and hence to find support for hypotheses (Greene, 2003). The results I presented are not because of multicollinearity, but in spite of it. Though, one caveat is that multicollinearity can make parameter estimates sensitive to small changes in the data (Greene, 2003). To explore this possibility I use three alternative methods: robust regression, bootstrapping, and switching regression. Robust regression and bootstrapping explore how sensitive the estimates are to changes in the data. Switching regression removes the need to include highly collinear interaction terms with vertical integration by splitting the sample by vertical integration.

First, robust regression in Stata 10.1 iteratively adjusts the weights of observations based on the absolute residuals (StataCorp, 2005). Observations with larger absolute residuals get less weight than those with small residuals. Because in OLS the sum of residuals squared is minimized, robust regression gives less weight to influential observations. If multicollinearity makes the estimates very sensitive to small changes in the data, then this effect should be most pronounced when the most influential observations are weighted differently. This is precisely what robust regression does.

Figure 3.5 reports the robust regression results for trust. The independent variables are the same as for the OLS regressions as reported in Figure 3.3. The even numbered models include a non-selection hazard. Because its coefficient is not significant in any model, I focus on the odd numbered models. The average effect of vertical integration is negative ($p = .06$) in model 1, which includes only the control variables besides vertical integration. If I include buyer asset specificity as an additional control (model 3), the effect becomes insignificant similar to the earlier finding that the effect of vertical integration is not significantly different from zero. Hypothesis 1 on the positive moderation effect of buyer asset specificity is again supported, as the interaction effect

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Vertical integration	-0.33 *	-0.64 *	-0.25	-0.15	-2.43 **	-2.88 ***	-1.85 **	-1.37	-0.58 **	-0.52
	(0.17)	(0.37)	(0.18)	(0.34)	(0.94)	(1.06)	(0.88)	(1.13)	(0.27)	(0.47)
Buyer asset specificity					0.37 **	0.43 ***				
* Vertical integration					(0.16)	(0.16)				
Relationship duration							0.55 **	0.45		
* Vertical integration							(0.27)	(0.32)		
Employee co-location									0.25 ***	0.22 **
* Vertical integration									(0.09)	(0.10)
Buyer asset specificity			-0.05	-0.07 *	-0.06 *	-0.07 **	-0.06 *	-0.07 *	-0.06 *	-0.07 **
			(0.03)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)
Relationship duration							-0.14 *	-0.16 *	-0.10	-0.13
							(0.08)	(0.09)	(0.08)	(0.08)
Employee co-location									-0.06	-0.04
									(0.07)	(0.07)
Supplier asset specificity	0.09 *	0.10 *	0.11 **	0.10 **	0.11 **	0.10 *	0.11 **	0.11 **	0.08	0.09 *
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Technological ability	0.15 ***	0.16 ***	0.16 ***	0.17 ***	0.15 ***	0.16 ***	0.16 ***	0.17 ***	0.16 ***	0.17 ***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Ford	-0.18	-0.07	-0.18	-0.14	-0.19	-0.10	-0.11	-0.12	-0.02	0.00
	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)
Buyer history	-0.22 ***	-0.22 ***	-0.21 ***	-0.20 ***	-0.22 ***	-0.21 ***	-0.22 ***	-0.19 **	-0.15 **	-0.14 *
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.07)	(0.08)
Non-selection hazard		0.23		-0.07		0.09		-0.16		0.00
		(0.22)		(0.22)		(0.22)		(0.24)		(0.27)
Constant	-0.29	-0.32	-0.22	-0.16	-0.08	-0.06	0.18	0.12	0.08	0.06
	(0.36)	(0.37)	(0.37)	(0.38)	(0.37)	(0.38)	(0.42)	(0.43)	(0.40)	(0.42)
F	8.71 ***	7.59 ***	7.78 ***	7.19 ***	7.63 ***	7.35 ***	6.67 ***	6.43 ***	5.29 ***	5.31 ***
N	241	223	241	223	241	223	224	211	212	199
Df_m	5	6	6	7	7	8	8	9	9	10
Adj. R2	0.14	0.15	0.15	0.16	0.16	0.19	0.17	0.19	0.15	0.18

Figure 3.5. Treatment effect model (robust regression) of trust[5]

between buyer asset specificity and vertical integration is positive ($p = .02$ in model 5). Likewise hypothesis 2 on the positive moderation effect of relationship duration receives support, because the interaction effect between relationship duration and vertical integration is positive ($p < .05$). Finally, the results are supportive of the positive moderation effect of employee co-location (hypothesis 3). The interaction effect between employee co-location and vertical integration is positive ($p < .01$). An inspection of the magnitude of the coefficients reveals that the results for robust regression are very similar to those of OLS. This suggests that the results are not driven by a few observations and are robust to different weightings of the data. Multicollinearity does not seem to cause major problems.

Second, under bootstrapping a new dataset is generated by drawing observations with replacement from the original dataset until the number of observations in the new dataset is the same as in the original dataset. Some observations may appear multiple times in the new dataset, others once, and some not at all. An OLS model is estimated on the new dataset, generating a set of coefficient estimates. For each model, I repeated

[5]* p < .1; ** p < .05; *** p < .01 in a two-tailed test. Standard errors are in parentheses.

this procedure 1000 times (i.e. 1000 new datasets were generated). For each coefficient a standard error is calculated from the 1000 replications. The standard error can then be used to construct a confidence interval around the original coefficient estimate (as that still provides the best unbiased estimate (Greene, 2003)). Hence, bootstrapping provides an alternative method to investigate how sensitive the estimates are to changes in the data.

Because the point estimates are the same as the OLS results in Figure 3.3, I discuss here only the standard errors and the significance levels (see Figure 3.6 for full results). In general, the results are very similar to the ones reported earlier. The non-selection hazard remains insignificant in all models. The average effect of vertical integration is not significant (models 1 and 3). Buyer asset specificity positively moderates the effect of vertical integration ($p = .02$ in model 5, hypothesis 1 supported). The significance level for the interaction between relationship duration and vertical integration is slightly lower ($p < .10$ in model 7), leading to moderate support for hypothesis 2. The significance level for the interaction between employee co-location and vertical integration is about the same ($p = .07$ in model 9), which suggests that hypothesis 3 is marginally supported. All in all, the bootstrap standard errors are similar to those obtained directly under OLS, leading to the same pattern of support for the hypotheses. This suggests that the results are not sensitive to small changes in the data.

Third, switching regression is another approach to assess the influence of multicollinearity. In this approach the model is estimated separately for the subsamples of internal and external suppliers. Because a moderation effect is evaluated through the comparison of coefficients across models, I do not have to rely on an interaction effect that potentially has high correlation with other independent variables. For example, a positive interaction effect of buyer asset specificity and vertical integration on trust implies that the effect of buyer asset specificity on trust should be greater in the subsample of internal than external suppliers.

[6]* p < .1; ** p < .05; *** p < .01 in a two-tailed test. Bootstrap standard errors are in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Vertical integration	-0.27	-0.55 *	-0.17	0.04	-2.26 **	-2.47 **	-1.53	-1.02	-0.42 *	-0.12
	(0.18)	(0.33)	(0.19)	(0.30)	(0.93)	(1.20)	(0.94)	(1.68)	(0.22)	(0.48)
Buyer asset specificity					0.35 **	0.40 **				
* Vertical integration					(0.15)	(0.18)				
Relationship duration							0.48 *	0.40		
* Vertical integration							(0.29)	(0.47)		
Employee co-location									0.22 *	0.19
* Vertical integration									(0.12)	(0.13)
Buyer asset specificity			-0.07 **	-0.10 ***	-0.08 **	-0.10 ***	-0.08 **	-0.09 **	-0.07 *	-0.08 **
			(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)
Relationship duration							-0.15 *	-0.20 **	-0.11	-0.15 *
							(0.08)	(0.09)	(0.08)	(0.09)
Employee co-location									-0.12	-0.11
									(0.09)	(0.08)
Supplier asset specificity	0.11 **	0.12 *	0.13 **	0.13 **	0.13 **	0.14 **	0.14 **	0.13 **	0.12 *	0.11 *
	(0.05)	(0.06)	(0.05)	(0.06)	(0.05)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
Technological ability	0.17 ***	0.18 ***	0.17 ***	0.19 ***	0.17 ***	0.18 ***	0.18 ***	0.19 ***	0.18 ***	0.20 ***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)
Ford	-0.14	-0.06	-0.16	-0.15	-0.17	-0.13	-0.09	-0.10	-0.02	-0.03
	(0.12)	(0.14)	(0.12)	(0.13)	(0.12)	(0.13)	(0.13)	(0.13)	(0.13)	(0.14)
Buyer history	-0.20 ***	-0.20 **	-0.19 ***	-0.17 **	-0.20 ***	-0.18 **	-0.18 **	-0.15 *	-0.11	-0.10
	(0.07)	(0.08)	(0.07)	(0.08)	(0.07)	(0.08)	(0.08)	(0.09)	(0.08)	(0.09)
Non-selection hazard		0.19		-0.14		-0.01		-0.19		-0.17
		(0.23)		(0.22)		(0.25)		(0.28)		(0.31)
Constant	-0.60	-0.68 *	-0.45	-0.46	-0.32	-0.36	-0.12	-0.10	-0.33	-0.28
	(0.38)	(0.41)	(0.36)	(0.38)	(0.36)	(0.38)	(0.47)	(0.44)	(0.43)	(0.44)
N	241	223	241	223	241	223	224	211	212	199

Figure 3.6. Treatment effect model (bootstrap OLS regression) of trust[6]

Figure 3.7 presents the results of the switching regressions. Each model is estimated separately for the internal suppliers (odd numbered models) and external suppliers (even numbered models). The fit of the models is good ($p < .01$), except for the subsample of internal suppliers once employee co-location is included. Due to missing observations the number of internal suppliers drops from 30 (model 1) to 19 (model 9; or to 17 in model 11 with non-selection hazard). Because of the poor model fit in models 9 and 11, I cannot use the switching regression to provide an additional test of the moderation effect of employee co-location (hypothesis 3). To facilitate comparison across sub-samples (necessary to test for moderation effects), I calculate robust standard errors from a combined variance-covariance matrix using the seemingly unrelated estimation algorithm in STATA 10.1.[7] Because the non-selection hazards are not significant in the models with good fit, I look at the models without non-selection hazard.

The effect of buyer asset specificity on trust is greater for internal (model 1) than external suppliers (model 2). Based on a statistical comparison of the coefficients, this

[7]Using a common variance-covariance matrix to construct robust standard errors is useful because it eliminates the effect of unequal sub-sample sizes and correlations in the error terms across the two equations on the standard errors used to statistically compare coefficients across models.

[8]* $p < .1$; ** $p < .05$; *** $p < .01$ in a two-tailed test. Robust standard errors are in parentheses.

	(1) Int.	(2) Ext.	(3) Int.	(4) Ext.	(5) Int.	(6) Ext.	(7) Int.	(8) Ext.	(9) Int.	(10) Ext.	(11) Int.	(12) Ext.
Buyer asset specificity	0.27 ***	-0.08 **	0.38 ***	-0.13 ***	0.30 ***	-0.10 **	0.36 ***	-0.11 ***	0.37 **	-0.08 **	0.44 ***	-0.10 ***
	(0.10)	(0.04)	(0.11)	(0.04)	(0.09)	(0.04)	(0.13)	(0.04)	(0.16)	(0.04)	(0.13)	(0.04)
Relationship duration					0.26	-0.16 *	0.39	-0.23 ***	0.23	-0.13	0.56 **	-0.20 **
					(0.22)	(0.09)	(0.33)	(0.09)	(0.27)	(0.09)	(0.28)	(0.09)
Employee co-location									0.13 *	-0.11	0.21 ***	-0.12
									(0.07)	(0.08)	(0.06)	(0.09)
Supplier asset specificity	0.26	0.12 **	0.32	0.10	0.18	0.13 *	0.17	0.12 *	-0.05	0.12 *	-0.06	0.11
	(0.20)	(0.06)	(0.24)	(0.06)	(0.19)	(0.07)	(0.22)	(0.07)	(0.20)	(0.07)	(0.19)	(0.07)
Technological ability	0.07	0.18 ***	0.04	0.21 ***	0.11	0.18 ***	0.09	0.20 ***	0.18	0.19 ***	0.01	0.21 ***
	(0.10)	(0.04)	(0.10)	(0.04)	(0.09)	(0.04)	(0.09)	(0.04)	(0.11)	(0.04)	(0.08)	(0.05)
Ford	-0.64 **	-0.10	-0.41	-0.11	-0.45	-0.03	-0.40	-0.04	-0.49	-0.02	0.04	-0.04
	(0.31)	(0.15)	(0.47)	(0.15)	(0.29)	(0.15)	(0.39)	(0.15)	(0.40)	(0.16)	(0.43)	(0.16)
Buyer history	-0.24 ***	-0.16 *	-0.24 *	-0.11	-0.28 **	-0.14	-0.34	-0.10	-0.22	-0.12	-0.11	-0.10
	(0.09)	(0.09)	(0.13)	(0.10)	(0.11)	(0.10)	(0.22)	(0.10)	(0.16)	(0.10)	(0.20)	(0.10)
Non-selection hazard			0.30	-0.48			0.33	-0.35			0.88 ***	-0.51
			(0.33)	(0.31)			(0.42)	(0.32)			(0.31)	(0.35)
Constant	-2.53 **	-0.46	-3.93 **	-0.48	-3.12 **	-0.11	-3.93 **	-0.09	-2.67 **	-0.18	-5.28 ***	-0.08
	(1.18)	(0.47)	(1.57)	(0.44)	(1.23)	(0.49)	(1.66)	(0.45)	(1.18)	(0.50)	(1.19)	(0.46)
F	9.02 ***	5.20 ***	7.55 ***	5.20 ***	10.22 ***	4.51 ***	7.52 ***	4.33 ***	1.37	4.07 ***	1.74	3.89 ***
N	30	211	26	197	24	200	22	189	19	193	17	182
Df_m	5	5	6	6	6	6	7	7	7	7	8	8
Adj. R2	0.28	0.15	0.27	0.19	0.31	0.17	0.26	0.21	0.02	0.17	0.06	0.21

Figure 3.7. Switching regression (OLS) of trust[8]

difference is statically significant ($p < .01$). This is supportive of hypothesis 1, in which I argue that trust in internal suppliers relative to trust in external suppliers increases with buyer asset specificity.

The effect of relationship duration on trust is greater for internal (model 5) than external suppliers (model 6). This difference is (marginally) significant ($p = .07$). This is supportive of hypothesis 2, in which I argue that trust in internal suppliers relative to trust in external suppliers increases with relationship duration.

3.4.2. Limitations

Like any study, ours also has limitations. For each procurement relationship I surveyed a single respondent, who was identified as the most knowledgeable informant. This approach is consistent with most prior research on vertical relationships (e.g. Heide and John, 1990; Poppo and Zenger, 1998; Artz and Brush, 2000; Poppo and Zenger, 2002; Kotabe et al., 2003). As other researchers have noted (Artz and Brush, 2000), typically only one individual interacts closely enough with each supplier to be able to provide sufficiently detailed information. Our data about trust are open to criticism for possibly being one sided, as the measures represent the opinion of the buyers alone. However, I believe that the buyer's opinion of trust must correlate reasonably well with the suppliers, failing which suppliers would have exited the relationship. The average relationship duration in the sample is 15 years. While most of our independent variables capture objective facts that can be measured through single items, three of them (buyer and supplier asset specificity, and technological ability) capture subjective opinions. The use of multiple indicators for these would enhance construct validity in future research.

Finally, our data is cross-sectional. While the procurement mode decision was made well before trust was measured within these procurement relationships, it could be that pre-existing levels of trust (unobserved to us) influenced the choice of procurement mode and are systematically related to present trust levels. I found no evidence for this when I corrected for the possible endogeneity of procurement mode through the Heckman selection model. However, trust differences for short relationships (see Figure 3.4) indicate that initial levels of trust may vary across procurment modes. Longitudinal data could help shed light on these issues.

Despite these data limitations, I feel that the data's unique feature – having comparable data across different governance modes – provides us an excellent opportunity to gain a better understanding of how trust interacts with firm boundaries.

3.5. Discussion

I find that the average effect of vertical integration on trust is not statistically different from zero. In the sample the two opposing effects of vertical integration on incentives and on trustworthy behavior – better aligned, yet weaker incentives – seem to cancel out. There is no reason why these should cancel out exactly in other settings than the one I have studied. It may very well be that in different settings the average effect of vertical integration is positive, or negative.

While this specific finding may not generalize, I expect that in a given setting changing one of the above effects relative to the other should lead to non-zero effects of vertical integration. This is the approach I took in hypothesis 1. There I argued (and found) that a higher scope for opportunism (through higher buyer asset specificity) increases trust in an internal supplier relative to trust in an external supplier.

Consistent with hypothesis 2 the interaction effect of vertical integration with relationship duration is positive. The main effect of relationship duration is negative (p = .08 in model 5, Figure 3.3). This represents the effect of relationship duration on trust for external suppliers. The effect for internal suppliers is positive but not significant. This is somewhat surprisingly given that prior literature has argued for and found evidence consistent with an increase in trust between firms as a result of a shared history. However, my theory is independent of the direction of the relationship duration effect on internal and external trust, as long as the effect is greater on internal than external trust. I argue that a prior relationship provides information that leads to updated trust beliefs, and that such trust revisions are more favorably internally than externally. It may very well be that trust beliefs are revised downward as a consequence of this information that surfaced during the relationship.

Another explanation is that in the sample external suppliers performed worse during the relationship than internal suppliers. The difference in the relationship duration effect could then be due to difference in performance, rather than differential attributions. However, this explanation is not likely given the estimation procedure and data. First, through the inclusion of a non-selection hazard I control for any unobserved or omitted characteristics including performance. Second, in the data I have measure of performance at the time of the survey and find a negative association between performance and vertical integration (for further analysis see Gulati and Nickerson, 2008). Finally, the negative linear effect of relationship duration on external trust may mask some interesting non-linear effects. Possibly, the effect is positive for some range of prior relationship. Because the direction of the effect is not central to my theory I do not explore this option here. See Gulati and Sytch (2008) for a further discussion of this point.

3.6. Conclusion

Trustworthiness of exchange partners cannot be directly observed but must be inferred from their actions. Because the behavior of a trustworthy exchange partner without incentives can be similar to the behavior of an untrustworthy exchange partner with incentives, a basic attribution problem exist. Does observed cooperation arise because the other is trustworthy or because the other has strong incentives to perform? This attribution problem is more prevalent if incentive intensity is higher.

Because incentive intensity is higher under non-integration than vertical integration, I can predict that exchange partners need more information about an external than internal unit to classify them as trustworthy. In line with this prediction I find that trust between exchange partners increases more with relationship duration under vertical integration than non-integration, and trust between exchange partners increases more with the extent to which employees of the partners are co-located under vertical integration than non-integration.

CHAPTER 4

Vertical Integration and Written Agreements

4.1. Introduction

In theories of economic organization, firms and markets are key alternatives to structure economic activity (Coase, 1937). An important difference between these alternatives is how production resources are allocated between activities. Whereas markets rely on prices to direct resources (Hayek, 1945), authority fulfills this role in firms (Coase, 1937). While a clear demarcation between firms and markets has clear conceptual benefits, it soon became obvious that this dichotomy ignored an interesting set of empirical relationships. In particular, independent firms may develop long-term contractual relationships with each other (Williamson, 1985, 1991). In such relationships firms transacts with each other within the framework of a written agreement, rather than as anonymous actors through a market. Written agreements combine elements of the price system typical of markets and hierachical elements characteristic of firms (Stinchcombe, 1985). Some argue that this intermediate form is even more prevalent than either pure markets or hierarchies (Stinchcombe, 1985; Powell, 1987; Hennart, 1993). This empirical prevalence has spurred research into the role and form of written agreements between firms (Crocker and Reynolds, 1993; Luo, 2002; Poppo and Zenger, 2002; Corts and Singh, 2004; Kalnins and Mayer, 2004; Mayer and Argyres, 2004; Argyres et al., 2007; Ryall and Sampson, 2008; Vanneste and Puranam, 2009).

An important role of contracts is incentive alignment. In transaction cost economics, contracts are seen as offering (imperfect) protection against opportunistic behavior (Williamson, 1975; Klein et al., 1978; Williamson, 1985). Contractual clauses place penalties on noncooperative behavior, making such behavior less likely, or at least offering compensation in the event of such behavior. Property rights theorists view contracts as spelling out specific rights to ensure that a non-owner uses the asset in such a way that the interests of the owner are not harmed (Grossman and Hart, 1986; Hart and Moore, 1990).

When describing market relationships, scholars of economic organization point to the importance of formal agreements between firms. Yet, formal agreements may also play an important role within firms. Just as Stinchcombe (1985) points out that hierarchical elements may exist within external relationships, contractual elements may be used within internal relationships. While obviously the legal status of internal agreements is different or absent, internal agreement can be used to align incentives of exchange partners.

In this study I explicitly compare and contrast written agreements within and between firms. I have access to an unique setting in which I can simultaneously observe internal and external agreements for similar transactions. My empirical setting is a Dutch production facility of a company active in the raw materials industry. To maintain their production equipment they rely on internal and external suppliers and use written agreements for both. I have access to all written agreements between 2001 and 2007. I compare internal and external documents on a per clause basis, with a special focus on the role of incentive clauses.

This research helps advance theory in two ways. First, I provide further documentation on how internal and external vertical relationships differ. This topic received much theoretical attention, yet little empirical scrutiny. Second, this research provides a greater understanding of the incentive consequences of formal agreements, and how these differ internally versus externally. In addition, because internal agreements are not legal documents, I can infer what other roles formal agreements have by studying internal agreements.

4.2. Theory

A contract is "an agreement which is legally enforceable or legally recognized as creating a duty" (Atiyah, 1989, p. 40). The precise role ascribed to contracts differs by theoretical lens. In agency theory, the use of contracts is twofold: incentive alignment and risk sharing (Eisenhardt, 1989*a*). In transaction cost economics contracts are seen as offering (imperfect) protection against opportunistic behavior (Williamson, 1975; Klein et al., 1978; Williamson, 1985). Contractual clauses place penalties on non-cooperative behavior, making such behavior less likely, or at least offering compensation in the event of such behavior. Property rights theorists view contracts as spelling out specific rights to ensure that the non-owner uses the asset in such a way that the interests of the owner are not harmed (Grossman and Hart, 1986; Hart and Moore, 1990). In all these economic theories, the main purpose of contractual clauses is to mitigate inefficiencies created by incentive conflict.

Internal agreements have limited or no legal enforceability. Exchange partners are reluctant to involve courts into internal disputes, because a legal court is unlikely to provide better solutions than a firm's authority can. Furthermore, because exchange partners belong to the same firm, going to court is equivalent to suing oneself. Finally, even if internal disputes are put to a court, judges are often unwilling to interfere in business decisions (other than those related to "bad faith" or "corrupt motives") (Williamson, 1991). Nonetheless, internal agreements can still provide incentive alignment between business units to the extent that agreements are enforced by top management. Thus, one expects no typical legal clauses in internal agreements (such as liabilities or force majeure clauses). On the other hand, internal agreements may contain incentive clauses like penalties or key performance indicators.

While effective agreements can help to mitigate incentive conflicts among transacting parties, writing such agreements is both cognitively challenging as well as costly. Given bounded rationality, it is problematic or even impossible to foresee all future relevant contingencies at the beginning of a transaction (Simon, 1957). Hence, agreements necessarily leave out some relevant detail (Williamson, 1975, 1985).

Prior research has sought to explain when and what types of clauses are included in agreements. For example, Corts and Singh (2004) and Kalnins and Mayer (2004) investigate what types of price clauses are included in agreements between firms. Relatedly, other work looks at the effect of a prior history between exchange partners on the contracts that they use (Crocker and Reynolds, 1993; Parkhe, 1993; Luo, 2002). In particular, the focus is on how partners learn to contract - i.e. how over time they figure out what should be included in contracts (Mayer and Argyres, 2004; Argyres et al., 2007; Ryall and Sampson, 2008; Vanneste and Puranam, 2009). Another important consequence of repeated interactions is trust (see chapter 3). Poppo and Zenger (2002) and Puranam and Vanneste (2009) explore the many ways in which trust affects the agreements between exchange partners. While collectively these studies provide a good understanding of the factors that drive variation in agreements between exchange partners, all these studies look at agreements between firms and not within firms. We know quite a lot about the choices that are made when it comes to external agreements, but do not know how these choices differ when it comes to internal agreements.

In addition, while prior research focused on how formal agreements can facilitate cooperation (e.g. Williamson, 1985; Grossman and Hart, 1986), recently it has been argued that formal agreements also have an important coordination role (Mayer and Argyres, 2004; Vanneste and Puranam, 2009). Cooperation is the alignment of incentives and coordination is the alignment of action (Gulati et al., 2005). Both cooperation and coordination are necessary for any collaborative action, and neither is individually sufficient (Gulati et al., 2005). An agreement provides a blueprint for conducting an exchange (Macaulay, 1963). This blueprint captures the roles and responsibilities of each party, and documents mutual expectations which allow companies to align their actions (Mayer and Argyres, 2004). Thus an agreement, like other forms of governance, is also an important coordination device (Gulati et al., 2005).

Even though the link between formal agreements and coordination was not made until recently, the study of coordination has a long history in organization theory (Barnard, 1938; Simon, 1945; March and Simon, 1958; Thompson, 1967). For example, Simon (1945, p. 81) illustrated the difference between cooperation and coordination as follows:

> "Perhaps it would clarify discussion of administrative theory to use the term "cooperation" for activity in which the participants share a common goal, and "coordination" for the process of informing each as to the planned behaviours of the others. Hence, cooperation will usually be ineffective – will not reach its goal, whatever the intentions of the participants in the absence of coordination."

Coordination is the inevitable consequence of division of labor. A key mechanism to achieve coordination is by plan (March and Simon, 1958; Galbraith, 1973; Tushman and Nadler, 1978). If interdependencies are known and stable, the alignment of actions can be pre-specified in a formal document. The document captures how actions are linked to each other, and who needs to do what when. Plans or formal documents make the coordination rules explicit.

Exchange partners can also implicitly coordinate through the use of common ground (Srikanth and Puranam, 2007; Puranam and Gulati, 2008). Clark (1996, p. 93) defines common ground as "the sum of their mutual, common or joint knowledge, beliefs and suppositions". Common ground enables coordination because it allows exchange partners to anticipate and interpret each other's actions.

Kogut and Zander (1992, 1996) argue that the existence of such common ground gives internal relationship coordination advantages over external relationships. This common ground consist of codes, classifications, and higher order organizing. Common ground forms more easily within firms than between firms because of more frequent interactions and through the emergence of a shared identity (which is strongly dependent on the location of firm boundaries). If common ground is more prevalent within than between firms, then it follows that coordination should be easier internally than externally.

Interestingly, and in contrast to work on contracts and cooperation, most empirical work on coordination focuses exclusively on relationships within firms (e.g. Van de Ven et al. (1976)). A notable exception is Puranam and Gulati (2008), who test ideas about common ground in the context of vertical relationships within and between firms.

They argue and find that (because of the presence of common ground) the amount of information shared between partners is lower within than between firms. In effect, external partners use more explicit communication in the absence implicit rules that could achieve the same result.

In similar vein, in this study I explore the differences in internal and external agreements. In contrast to Puranam and Gulati (2008) who look at information sharing during the relationship, I focus on those aspects of coordination specified prior to the transaction. In addition, I also concentrate on the cooperation aspects of agreements, which is equivalent to incentive alignment (and in line with the dissertation's main theme of incentives and firm boundaries). In chapter 2 incentive alignment comes from the promise of future business. In this chapter incentive alignment comes from explicit formal rules and penalties in agreements between exchange partners.

4.3. Methods

4.3.1. Setting

The trade-off between internal and external validity is an important issue in the selection of any empirical setting. Internal validity concerns the establishment of a relationship between two constructs. External validity is the degree to which this relationship holds across organizations and industries (Shadish et al., 2002). Given the lack of comparative empirical evidence, I place stronger emphasis on internal validity in this study. I choose to study internal and external agreements from a single company. Through this approach I implicitly control for many factors that would have been difficult to control for explicitly (e.g. characteristics of the industry, company, and products).

My empirical setting is a company active in the raw materials industry across multiple continents. The industry makes use of highly capital intensive equipment that requires a lot of maintenance. Due to the sensitivity of the data, I cannot reveal the name of the company. For this research, I have access to their production site in The Netherlands. For their maintenance services, they rely on internal and external suppliers and use purchasing agreements for both. The internal supplier is organized as a separate unit within the production unit. The vast majority of external suppliers is located in the Netherlands, many of them in close proximity to the production site. From a research point of view, a very attractive feature of this setting is that internal and external suppliers provide very similar services (even to the extent that for some service categories the company makes use of both internal and external suppliers). This unique setting allows me to evaluate formal agreements within and between firms for similar transactions.[1] Through the research design I am able to limit the variation in service characteristics, which helps me to isolate the effect of vertical integration on formal agreements. If internal and external suppliers were to provide completely different services, then it would have been difficult to evaluate how much of the variation in agreements is due to vertical integration versus due to differences in services.

The unit of analysis is the purchase of a maintenance service, which include mechanical, electrical, and hydraulic services. The equipment in need of maintenance ranges from small pieces, which are easily moveable by one person, to enormous, multi tonnes machinery that can only be moved with the help of cranes and often require on-site maintenance.

4.3.2. Data

I use data from three sources. First, I have access to all maintenance service purchasing agreements with the internal and external suppliers between 2001 and 2007 inclusive. The agreements are between the buyer and the provider of the service. The buyer can be one or multiple units of the focal company. The supplier is either part of the same company ("internal") or of a different company ("external"). The sample consists of 203 agreements, of which 108 are internal and 95 external.

Two research assistants coded independently the contents of all agreements. This enormous effort of coding a total of 5536 pages (!) took several months. The coders used a coding scheme that was meant to capture exhaustively the different clauses

[1] While the setting is exceptional in terms of comparability of the internal and external transactions, internal documents to facilitate transactions within firms are quite common. In fieldwork partly discussed in chapter 2, I came across several instances of internal agreements at different companies.

in the agreements. I devised the scheme on the basis of 30 agreements selected from the sample on the basis of diversity. I carefully went through each agreement and constructed categories to capture different type of clauses (e.g. payment condition, monitoring). For each category I provided a definition, the possible answer categories to capture the extent to which the category is specified in an agreement, and instructions about the types of clauses that fall and do not fall under the given category. The different categories are explained in detail below under "dependent variables". The scores of both coders on the different categories showed high congruence. If the coders assigned a different score to a contract, I went back to the contract and decided which score should be applied.

Second, I relied on contract specialists for the classification of the services in each agreement. The company distinguishes among seventeen broad service groups, such as hydraulics systems, engine revisions, and low and high voltage. Each group contains between one and five categories for further classification, resulting in 62 categories in total. A contract specialist categorized the services of each internal agreement into one or more of these 62 categories. Another contract specialist did the same for the external agreements. If a specialist had doubts about the correct category, a colleague was asked for help. An agreement can be categorized in multiple categories if it describes more than one service.

Third, I use the company's archival records to obtain detailed information about each service category. The company collects and maintains data to capture the company specificity and risk for each category. These data are used for strategic planning, for make or buy decisions, and for determining how the internal supply unit can add most value. For each category they collect data on seven dimensions. I discuss one dimension, production loss, here as an example and discuss the others in more detail below under "control variables". The company wants to know the extent to which production loss is an important issue for each category. Because it is difficult to obtain objective figures, they rely instead on the subjective assessment of multiple service specialists from the supplying unit and buying unit for each category. Specialists are asked to indicate the extent to which production loss is an important factor on a five point scale (1 = "not at all relevant" and 5 = "very relevant"). The final outcome is a production loss consensus score for each of the 62 service categories.

I am able to use archival records for 2008, whereas all agreements in the sample are signed before 2008. A concern is that the 2008 data may not be reflective of the conditions under which the agreement was drafted. Luckily, it turns out that company specificity and risk for each service are fairly stable over time. I compared the 2008 data for each service category and dimension with the data for 2006. Most assessments were the same. For those assessments that were not, the differences were small. Because it was not possible to obtain the complete 2006 data, I use the 2008 data. Thus, while it would have been ideal to have the exact conditions at the time of signing the agreement, the current data may be a reasonable approximation of those conditions.

4.3.3. Measures

4.3.3.1. Dependent variables. All dependent variables are directly derived from the actual agreements. *Total pages* is the total number of pages of the agreement. *Price pages* is the number of pages in the agreement that provide information on prices. For example, actual prices, the different components that make up the total price, or how price can be changed. *Service pages* is the number of pages that describe the service(s) in detail. For example, which piece of equipment needs to be maintained and how often the service is required.

Buyer signatures is the number of people from the buyer who signed the agreement. *Supplier signatures* is the number of people from the supplier who signed the agreement.

Buyer contacts is the number of people from the buyer who are listed as contact, often with an email address or phone number. These contacts are often responsible for a specific part of the production process. Contacts are included in the agreement to facilitate communication between the parties. *Supplier contacts* is the number of people from the supplier who are listed as contact. These contacts are often responsible for a specific part of the service and serve as a first point of contact.

Notice of termination captures whether it is possible for one of the parties to cancel the contract without a specific reason. In an agreement this often is indicated explicitly as termination is possible "without stating reasons" or the duration of the contract is until "termination". *Agreement cancellation* is a dummy variable that is one if at least one of the parties can cancel the agreement for a specific reason. If no such clause is included, agreement cancellation is zero. Specific reasons include poor performance, agreement breach, and bankruptcy. An example is: "If supplier does not fulfil its obligations, or not in a timely manner, or if buyer may reasonably expect that supplier will not fulfil its obligations, or will not in a timely manner, or if supplier asks for bankruptcy protection, then buyer has the right to directly and unilaterally cancel the agreement by recorded mail without judicial intervention." *Penalties* is a dummy variable indicating whether a clause in the agreement is related to penalties, i.e. financial or non-financial compensation in the event of underperformance. For example, "Supplier agrees to cooperate with audits and quality samples with respect to compliance of rules in this agreement. If audits or results from the samples are below satisfaction, or not in line with this agreement, the deviation from the norms will be taken as representative for the entire period between the most recent and previous testing. Supplier will correct any deviations and / or financially compensate buyer." *KPI* is a dummy variable that is one if an agreement contains at least one key performance indicator or the intention is expressed to develop one or more such indicators during the agreement period. KPI is zero otherwise. For example, "All activities are evaluated using a Balanced Score Card. Each quarter a total score is calculated on the basis of performance indicators and using the Balanced Score Card."

Payment condition is a categorical variable that can take on one of three values: fixed price, cost plus, or combination. Fixed price means that the supplier will get a lump sum payment in exchange for the completion of services as specified in the agreement, without regard for the supplier's actual costs. With cost plus pricing the supplier works on a particular task in exchange for a specified amount per hour plus other expenses such as materials. The total amount is not exactly known up-front.

Sometimes an agreement is a combination of both. For example, part of the agreement may be fixed price for a clearly specified job, while the other part may be priced on a cost plus basis (e.g. for incidentals).

Guarantee indicates whether the agreement specifies any guarantee conditions, and if so the length of time for which these hold. The possible categories are: not specified, 3 months, 12 months, or 24 months. For example, "All activities, repairs, revisions, and / or supplies have a guarantee of one year starting from the moment of activation of the installation."

Non-exclusive is a categorical variable with two possible answer categories: included and not included. An agreement may explicitly say that the buyer has the option of using alternative suppliers (exclusivity is "included"). For example: "This agreement is non-exclusive. Buyer maintains the right to procure from third parties or solicit tenders." If no conditions are specified, non-exclusive is "not included". While logically an exclusivity clause could be included to formally declare that a supplier will be the only supplier for the service specified and buyer will not use alternative suppliers, I found no such instances in this sample. *Subcontracting* is a categorical variable with two possible answer categories: included and not included. An agreement may specify that a supplier may use alternative suppliers to fulfil part of the task (subcontracting is "included"). For example, "Activities that the supplier cannot execute, can only be contracted out to subcontractors after prior written permission of buyer." If nothing is mentioned about subcontracting, then subcontracting is "not included". No agreement used a subcontracting clause to rule out the possibility of a supplier soliciting the help of third parties.

Relational dispute resolution is a dummy variable that indicates whether a procedure is documented to resolve disputes directly between buyer and supplier without the involvement of third parties. For example, "If deemed necessary, arbitration will be provided in a strategic meeting with the following participants, from the buyer the chief of unit [A] and chief of unit [B], and from the supplier the unit manager and client manager." *Outside arbitration* is one if a clause is related to external arbitration by a neutral outsider (but not a court, see below). For example, "All disputes, including those that are not recognized as such by one party, arising directly or indirectly from this agreement, that cannot be resolved through joint deliberations will eventually be resolved in accordance with the regulations of the Dutch Arbitration Institute, taking into account the following: i) the arbitration commission will consist of three arbitrators, appointed in accordance with the regulations referred to above, ii) the arbitration procedure will be conducted in the Dutch language, and iii) the arbitration commission will take a decision in accordance with the law." This variable is zero if no such clause is included. *Court* is one if a clause is included related to legal action or court of law. For example, "Disputes that arise directly or indirectly from this agreement are presented – with the exclusion of any other body – to the authorized court within the circuit where buyer is established." Otherwise, this variable is zero.

Meeting is a dummy variable that captures whether a meeting clause is present. Such clause specifies the timing and the purposes for which representatives of buyer and supplier get together. Typically, the reasons for meetings are evaluation and planning. For example, "Account manager of supplier and team leader of buyer have an operational meeting once every two months to discuss among other things: safety issues, budget control, improvement proposals, and performance indicators." *Order procedure* is a dummy variable that is one if and only if a clause is included in the agreement detailing how an order can be placed or how a service request should be conveyed. For example, "Supplier receives from buyer a SAP work order, which indicates: the order date, service requested, start or end date, order number, and agreement number. Without such work order supplier is not allowed to start its activities." *Contract change* is a dummy variable indicating if a clause recording how the agreement can be changed or how changes can be formalized is included. For example, "Adjustments or changes to the contract are not effective before they are added in writing to Appendix II of this agreement.

4.3.3.2. Independent variables. *Internal* is a dummy variable that is one if the exchange is internal (i.e. between units of the same company) and zero if it is external (i.e. between units of different companies).

4.3.3.3. Control variables. I include several control variables that might simultaneously impact the dependent and independent variables. For the first control variable I rely on the contract specialists' classification. *Categories* capture the total number service categories (out of a possible 62) that are covered in an agreement. As a bundle of services belongs to more categories, the inherent coordination and cooperation challenges increase. An agreement can be used to address these challenges (Williamson, 1975; Gulati et al., 2005).

For the next set of control variables, I use the company's archival records. Each of the 62 service categories is scored on seven dimensions: knowledge specificity, external availability, volume, safety, production loss, scale up, and speed. Because these dimensions are used in the make and buy decision and may affect the level of detail of the written agreement, we need to include them as control variables. Each score, a consensus score from multiple service specialists, is between one and five where one indicates "not at all relevant" and five means "very relevant". When an agreement covers more than one service, I calculate an overall score for each dimension as the average of all services. *Knowledge specificity* is the extent to which the required knowledge for a service is specific to the focal company. *External availability* is the extent to which external suppliers are available that have the required knowledge (reverse coded). *Volume* is the extent to which the company's required volume for a service is significant. *Safety* is the extent to which a service has important safety and environmental issues associated with it. *Production loss* is the extent to which the loss in production is significant should the service fail or be delivered late. *Scale up* is the extent to which the possibility to rapidly scale up service delivery is important both in terms of the number of people and the number of different technical disciplines required. *Speed* is the extent to which a quick response time of the service is important.

4.3.4. Analysis technique

While internal and external suppliers supply roughly similar maintenance services, and the control variables capture some important elements on which internal and external transactions may vary, internal and external transactions may still differ in ways that are unobserved. If these unobservable factors are correlated with the dependent variables and with whether the transaction is internal, then simply regressing the dependent variables on internal (and the control variables) leads to biased estimates (Wooldridge, 2002). The basic problem is that it is not clear whether variation in the agreement should be attributed to vertical integration or to the fact that services are (somewhat) different under vertical integration and non-integration.

I use a Heckman correction to control for unobserved characteristics that may simultaneously influence vertical integration and the dependent variables (Heckman, 1979). A model with Heckman correction is estimated in two steps. First, I estimate a probit model of vertical integration. I use the estimates of this model to calculate for each observation a non-selection hazard into vertical integration if internal or into non-integration if external, which takes into account the effect of unobservable variables that influence the vertical integration decision. Second, I use OLS to regress the dependent variables on internal, the control variables, and the non-selection hazard. By its inclusion, the non-selection hazard controls for any unobservable features of the relationships that might simultaneously affect the vertical integration choice and the dependent variables (Hamilton and Nickerson, 2003). For identification purposes, I include an auxiliary variable in the first model and exclude it from the second model. A good auxiliary variable is one that is strongly correlated with the choice to vertically integrate (step 1), but not correlated with the error term in the equation for detailedness of the written agreement (step 2) (Wooldridge, 2002). *January* is a dummy variable that captures whether the start date of an agreement is in January. Roughly 9% (or about one twelfth) of the external agreements begin in January, whereas 61% of the external agreements do. The company's budget year starts in January and internal agreements often adhere to this planning cycle. External agreements do not follow this tradition. Hence, January is correlated with the choice of governance mode (step 1). Contracts in January appear no different than those that do not begin in January. A contract specialist confirmed the lack of difference. If this is the case, then January is not correlated with the error term in the agreement detail equation (step 2) and is a useful auxiliary variable.

4.4. Results

In this section I report summary statistics for each dependent variable by type of agreement. If a dependent variable has sufficient variance per agreement type, I also present regression analyses without and with endogeneity correction (as discussed above). In Figure 4.1 the sample correlations and descriptive statistics are given.

4.4.1. Pages

For each agreement I capture three aspects of the number of pages: the total number of pages, the number of pages with price information, and the number of pages that give the specifics of the service. Figure 4.2 provides the sample averages for each by type of agreement. On average external agreements have 35.4 pages versus 20.1 for internal agreements. In the sample, external agreements are 76% longer than internal agreements. This is in part due to more price and service pages. A typical external agreement has 4.0 pages of price information versus 2.5 for an internal agreement. On average an external agreement has 9.0 pages with detailed service information and an internal agreement 6.8 pages.

Figure 4.3 reports the OLS regression results for the page dependent variables: total pages (model 1 and 2), price pages (model 3 and 4), and service pages (model 5 and 6). The main independent variable is internal, which is one if and only if the agreement is internal. The control variables are included in all models. The even numbered models include a non-selection hazard to control for any unobserved differences between internal and external transactions. The non-selection hazard is omitted from the odd

[2]Correlations greater than |.14| are significant at 5% level.

	Mean	S.D.	Min	Max	1.	2.	3.	4.	5.	6.	7.	8.
1. Internal	0.53	0.50	0	1								
2. Total pages	27.27	22.09	1	119	-0.35							
3. Price pages	3.23	4.53	0	53.55	-0.16	0.45						
4. Service pages	7.84	11.54	0	77.75	-0.09	0.83	0.18					
5. Buyer signatures	1.64	1.11	1	8	0.07	0.02	0.04	-0.01				
6. Supplier signatures	1.32	0.65	1	4	0.28	0.03	0.05	0.10	0.73			
7. Contacts buyer	2.40	4.04	0	36	-0.17	0.26	0.16	0.21	0.43	0.32		
8. Contacts supplier	2.53	3.53	0	25	0.14	0.39	0.07	0.38	0.03	0.10	0.32	
9. KPI	0.62	0.49	0	1	-0.36	0.27	0.21	0.17	0.25	0.35	0.35	0.02
10. Notice of termination	0.71	0.45	0	1	-0.55	0.56	0.23	0.30	0.15	-0.04	0.16	0.19
11. Agreement cancellation	0.52	0.50	0	1	-0.87	0.33	0.14	0.07	-0.10	-0.29	0.15	-0.18
12. Payment condition	0.92	0.36	0	2	0.12	0.09	0.09	0.08	-0.02	0.00	0.04	0.10
13. Order procedure	0.84	0.37	0	1	-0.41	0.42	0.19	0.24	0.11	0.01	0.17	0.17
14. Non-exclusive	0.31	0.46	0	1	-0.67	0.32	0.12	0.17	-0.10	-0.17	0.00	-0.13
15. Subcontract	0.49	0.50	0	1	-0.74	0.38	0.18	0.14	-0.03	-0.15	0.16	-0.13
16. Guarantee	4.94	6.02	0	24	-0.87	0.37	0.16	0.16	-0.09	-0.23	0.18	-0.10
17. Penalties	0.57	0.50	0	1	-0.82	0.33	0.29	0.06	-0.05	-0.21	0.15	-0.13
18. Contract change	0.53	0.50	0	1	-0.82	0.25	0.16	0.03	-0.10	-0.33	0.12	-0.17
19. Rel. dispute resolution	0.18	0.38	0	1	0.44	-0.11	0.07	0.00	0.49	0.71	0.17	0.10
20. Outside arbitration	0.01	0.10	0	1	-0.11	0.13	0.07	-0.03	0.03	0.03	0.39	0.00
21. Court	0.07	0.26	0	1	-0.30	0.05	-0.03	-0.11	0.08	-0.08	0.15	-0.07
22. Meeting	0.89	0.31	0	1	-0.30	0.34	0.16	0.19	0.17	0.15	0.17	0.18
23. Categories	2.72	2.35	1	19	-0.12	0.27	0.00	0.29	0.00	0.11	-0.05	0.07
24. Knowledge specificity	3.66	0.54	2	5	0.17	-0.13	-0.11	-0.07	0.11	0.10	-0.02	-0.06
25. External availability	3.47	0.56	1.80	4.60	0.41	-0.04	-0.17	0.03	0.08	0.09	-0.08	0.13
26. Volume	3.67	0.45	2.80	5	0.06	0.06	-0.06	0.06	0.17	0.20	-0.04	0.03
27. Safety	3.43	0.92	1.50	5	0.29	0.10	0.03	0.09	-0.02	0.04	-0.08	0.13
28. Production loss	3.55	0.58	1.80	4.67	0.38	0.00	-0.05	0.08	0.09	0.13	0.08	0.22
29. Scale up	3.37	0.74	1	5	0.02	0.21	0.04	0.21	-0.04	-0.05	0.02	0.16
30. Speed	3.40	0.75	1	5	0.25	0.13	0.04	0.14	-0.11	-0.10	-0.06	0.18
31. January	0.37	0.48	0	1	0.53	-0.15	-0.15	-0.04	-0.17	0.00	-0.24	0.16

	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
10. Notice of termination	0.26										
11. Agreement cancellation	0.35	0.55									
12. Payment condition	0.13	-0.05	-0.05								
13. Order procedure	0.31	0.52	0.43	0.09							
14. Non-exclusive	0.44	0.42	0.63	0.00	0.30						
15. Subcontract	0.49	0.51	0.75	0.05	0.38	0.67					
16. Guarantee	0.44	0.49	0.79	0.06	0.36	0.70	0.77				
17. Penalties	0.35	0.50	0.81	-0.08	0.42	0.59	0.65	0.71			
18. Contract change	0.33	0.52	0.87	-0.10	0.42	0.59	0.66	0.75	0.83		
19. Int. dispute resolution	0.26	-0.19	-0.45	0.03	-0.08	-0.28	-0.35	-0.38	-0.35	-0.44	
20. Outside arbitration	0.08	0.06	0.10	0.02	0.04	0.04	0.10	0.02	0.09	-0.01	-0.05
21. Court	-0.05	0.18	0.27	-0.30	0.12	0.05	0.03	0.03	0.25	0.23	-0.13
22. Meeting	0.34	0.45	0.30	0.01	0.40	0.23	0.31	0.29	0.33	0.34	0.16
23. Categories	0.09	0.19	0.08	-0.06	0.07	0.15	0.13	0.12	0.09	0.06	-0.01
24. Knowledge specificity	-0.09	-0.16	-0.16	-0.06	-0.01	-0.13	-0.19	-0.15	-0.17	-0.12	0.04
25. External availability	-0.27	-0.23	-0.42	-0.02	-0.34	-0.28	-0.41	-0.38	-0.44	-0.42	0.02
26. Volume	0.05	-0.03	-0.04	0.10	0.06	-0.03	-0.06	-0.08	-0.10	-0.09	0.12
27. Safety	-0.23	-0.08	-0.32	0.07	-0.23	-0.22	-0.25	-0.33	-0.33	-0.35	0.04
28. Production loss	-0.19	-0.17	-0.39	0.09	-0.18	-0.41	-0.35	-0.36	-0.31	-0.34	0.10
29. Scale up	-0.10	0.03	-0.09	0.19	0.04	-0.03	-0.01	0.09	-0.05	-0.13	-0.01
30. Speed	-0.24	-0.09	-0.31	0.16	-0.13	-0.20	-0.14	-0.14	-0.25	-0.30	-0.05
31. January	-0.38	-0.33	-0.53	-0.03	-0.41	-0.38	-0.44	-0.48	-0.48	-0.49	0.13

	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
21. Court	0.35										
22. Meeting	0.03	0.04									
23. Categories	-0.07	-0.09	0.14								
24. Knowledge specificity	-0.03	-0.20	-0.08	0.11							
25. External availability	0.00	-0.14	-0.18	0.17	0.52						
26. Volume	-0.04	-0.07	0.18	-0.02	0.31	0.40					
27. Safety	0.06	0.07	-0.09	0.03	-0.23	0.44	0.31				
28. Production loss	-0.01	-0.09	0.03	0.16	0.29	0.57	0.25	0.38			
29. Scale up	0.02	-0.28	0.18	0.20	0.26	0.20	0.25	0.09	0.37		
30. Speed	0.01	-0.23	-0.09	0.20	0.22	0.38	0.06	0.43	0.61	0.70	
31. January	-0.08	-0.22	-0.26	0.04	0.04	0.40	0.01	0.33	0.21	0.08	0.24

Figure 4.1. Pairwise correlations and descriptive statistics[2]

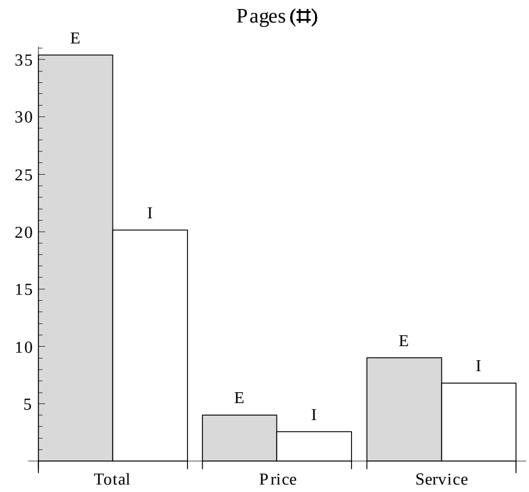

Figure 4.2. Average number of pages of external (E) and internal (I) agreements

numbered models. Model 1 predicts that external agreements have 15.66 ($p < .01$) more pages than internal agreements. This estimate is close to the difference in sample averages (as shown in 4.2). Services that span multiple categories are associated with longer agreements. Knowledge specificity is linked with shorter agreements. The other control variables are not significant. The model fit is good and the adjusted R^2 is 0.21. Controlling for unobserved transaction characteristics (model 2) leads to a slightly higher estimate of page difference between internal and external agreements: 18.92 ($p = .01$). However the non-selection hazard is not significant, which suggests that model 1 is appropriate.

Model 3 predicts that external agreements have 1.36 ($p = .07$) more price pages than internal agreements. This is in line with the difference in sample average. While the model fit is good according to the F-test, the adjusted R^2 is only .02. This is because none of the control variables are significant. In model 4 with endogeneity correction the non-selection hazard is not significant, suggesting that model 3 is appropriate.

Model 5 predicts that external agreements have 1.31 more service pages than internal agreements, though this point estimate is not significantly different from zero ($p = .41$). The model fit is good and the adjusted R^2 is 0.10. This model suggests that internal and external agreements allocate a similar number of pages to description of

	(1) Total pages	(2) Total pages	(3) Price pages	(4) Price pages	(5) Service pages	(6) Service pages
Internal	-15.66 ***	-18.92 **	-1.36 *	-1.58	-1.31	-5.12
	(3.21)	(7.56)	(0.74)	(1.34)	(1.60)	(3.51)
Categories	1.88 ***	1.74 ***	-0.02	-0.03	1.31 ***	1.14 ***
	(0.62)	(0.64)	(0.06)	(0.09)	(0.34)	(0.36)
Knowledge specificity	-6.60 **	-6.31 *	0.59	0.61	-3.55 **	-3.21 *
	(3.24)	(3.35)	(1.08)	(1.17)	(1.60)	(1.65)
External availability	2.35	3.16	-1.98	-1.92	0.65	1.59
	(3.55)	(3.63)	(1.73)	(1.54)	(1.52)	(1.62)
Volume	2.04	1.42	-0.39	-0.43	1.50	0.77
	(4.29)	(4.53)	(0.79)	(0.96)	(2.98)	(3.04)
Safety	2.05	2.34	0.80	0.82	0.18	0.52
	(2.18)	(2.35)	(0.93)	(1.02)	(1.15)	(1.19)
Production loss	-0.88	-0.26	0.26	0.30	0.11	0.84
	(2.88)	(3.18)	(0.52)	(0.65)	(1.88)	(2.05)
Scale up	4.67	4.47	0.03	0.02	3.00	2.76
	(2.90)	(2.92)	(0.36)	(0.36)	(1.98)	(1.99)
Speed	1.75	1.81	0.42	0.42	-0.28	-0.20
	(3.63)	(3.62)	(0.43)	(0.42)	(2.43)	(2.43)
Non-selection hazard		2.37		0.16		2.77
		(5.95)		(1.23)		(2.10)
Constant	13.44	11.20	4.94 ***	4.79 **	0.09	-2.54
	(11.28)	(10.80)	(1.89)	(1.86)	(6.64)	(6.73)
F	14.93 ***	15.40 ***	3.74 ***	3.46 ***	4.88 ***	5.42 ***
N	203	203	203	203	203	203
df_m	9	10	9	10	9	10
Adj. R2	0.21	0.21	0.02	0.02	0.10	0.10

Figure 4.3. OLS regressions of number of pages[3]

the service, once we control for transaction characteristics. For each additional category, the service description increases 1.31 ($p < .01$) pages in length. Model 6 with endogeneity correction also finds no statistical difference between internal and external agreements in terms of service pages. Again, the non-selection hazard is not significant and hence model 5 is appropriate.

Together these regression results suggest that the total number of pages of external agreements is higher than internal agreements. External agreements have more price pages but a similar number of service pages. This finding is in line with the additional role external agreements have. In contrast to internal agreements, external agreements also have an important legal function. As such external agreements may have several clauses that are not required internally, making the external agreements longer than the internal agreements.

[3] * $p < .1$; ** $p < .05$; *** $p < .01$ in a two-tailed test. Robust standard errors are in parentheses. For this and all other models with a non-selection hazard I also obtained bootstrap errors. The results are similar to the ones reported here.

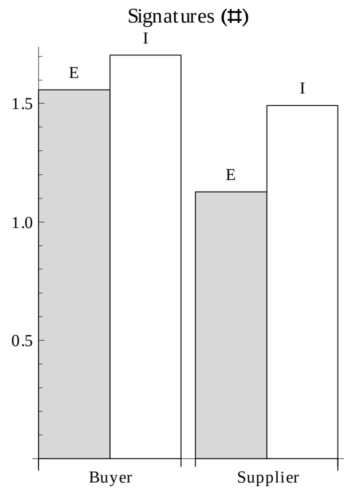

Figure 4.4. Number of signatures in external (E) and internal (I) agreements

4.4.2. Signatures

Figure 4.4 shows the average number of buyer and supplier signatures per agreement type. External suppliers tend to have just one representative, whereas the average signatures for internal buyers and suppliers is around 1.5.

The models in figure 4.5 provide a more detailed analysis taking into account observed and unobserved transaction characteristics. The dependent variables are buyer signatures in model 1 and 2 and supplier signatures in model 3 and 4. The control variables are the same as above. The even numbered models include a non-selection hazard to correct for possible endogeneity of internal, while the odd numbered models do not. The F-tests in model 1 and 2 are not significant. These models do not fit the data well, because for each model we cannot reject the hypothesis that all coefficients are zero. Model 3 suggests that internal suppliers place 0.48 ($p < .01$) signature more than external suppliers in their agreements. This is consistent with the observed sample averages. The model fit is good and the adjusted R^2 is 0.17. The non-selection hazard for endogeneity correction is not significant in model 4, which implies that model 3 is appropriate.

Together these results suggest that from the buyer's perspective the number of signatures does not depend on the agreement type, while internal suppliers tend to

[4]* $p < .1$; ** $p < .05$; *** $p < .01$ in a two-tailed test. Robust standard errors are in parentheses.

	(1) Buyer signatures		(2) Buyer signatures		(3) Supplier signatures		(4) Supplier signatures	
Internal	0.14		-0.77	**	0.48	***	0.16	
	(0.13)		(0.37)		(0.10)		(0.24)	
Categories	0.01		-0.03		0.06	**	0.04	
	(0.03)		(0.04)		(0.03)		(0.03)	
Knowledge specificity	0.18		0.26		0.11		0.14	
	(0.24)		(0.24)		(0.12)		(0.12)	
External availability	-0.11		0.11		-0.25	**	-0.18	
	(0.20)		(0.25)		(0.12)		(0.14)	
Volume	0.27		0.10		0.27	*	0.21	
	(0.35)		(0.35)		(0.16)		(0.16)	
Safety	0.04		0.12		0.04		0.07	
	(0.17)		(0.17)		(0.08)		(0.09)	**
Production loss	0.39	**	0.56	**	0.19	*	0.25	
	(0.20)		(0.24)		(0.11)		(0.12)	
Scale up	0.10		0.04		0.02		0.00	
	(0.21)		(0.20)		(0.11)		(0.11)	
Speed	-0.47	*	-0.45		-0.28	*	-0.27	
	(0.28)		(0.28)		(0.16)		(0.17)	
Non-selection hazard			0.66	**			0.23	
			(0.30)				(0.16)	
Constant	0.02		-0.60		0.45		0.24	
	(1.19)		(1.30)		(0.52)		(0.58)	***
F	1.57		1.60		3.85	***	3.51	***
N	203		203		203		203	
df_m	9		10		9		10	
Adj. R2	0.04		0.07		0.17		0.18	

Figure 4.5. OLS regressions of number of signatures[4]

place more signatures than external suppliers. While the difference between internal and external signatures is small, it is suggestive of the different roles signatures play in internal and external agreements. In an external agreement a signature implies legal responsibility. A signature of a single person is sufficient to represent the entire firm. Internally, legal responsibility is less important. Internally signatures may be more related to the involvement of different units and the decision making process, according to some of the people involved. If this is the case, then an additional signature has some function internally but less so externally (and we would expect to see more signatures internally than externally).

4.4.3. Contacts

About 66% of the agreements have at least one buyer contact and about 75% have at least one supplier contact. Figure 4.6 shows the average number of contacts per agreement type. More buyer contacts are included in external than internal agreements

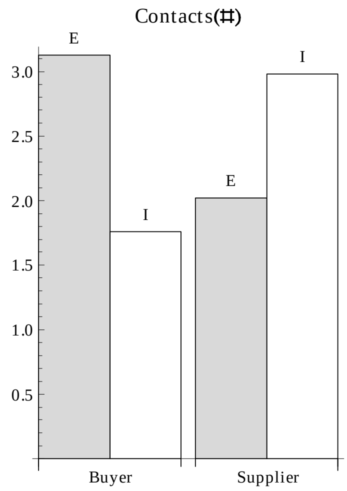

Figure 4.6. Average number of contacts in external (E) and internal (I) agreements

(3.1 versus 1.8). The opposite holds for supplier contacts, for which less are included in external contracts than internal contracts (2.0 versus 3.0).

Figure 4.7 reports the regression results for the dependent variable buyer contacts (model 1 and 2) and supplier contacts (model 3 and 4). A non-selection hazard is included for the even but not for the odd numbered models. The F-tests are significant for all models, yet the adjusted R^2s are low (between 0.05 and 0.07). Model 1 estimates that internal agreements have 1.81 ($p = .03$) fewer buyer contacts than external agreements. This estimate increases to 4.27 ($p < .01$) fewer buyer contacts in internal agreements, once we control for unobserved differences in transactions (see model 2). The non-selection hazard is significant. For supplier contacts, models 3 and 4 estimate more supplier contacts in internal agreements, though these point estimates are not significant.

Together these results suggest that internal agreements have less buyer contacts and the average number of supplier contacts is quite similar between internal and external agreements.

[5]* $p < .1$; ** $p < .05$; *** $p < .01$ in a two-tailed test. Robust standard errors are in parentheses.

	(1) Buyer contacts		(2) Buyer contacts		(3) Supplier contacts		(4) Supplier contacts	
Internal	-1.81	**	-4.27	***	0.64		1.23	
	(0.81)		(1.53)		(0.55)		(1.29)	
Categories	-0.17		-0.28	*	0.05		0.08	
	(0.11)		(0.14)		(0.08)		(0.10)	
Knowledge specificity	0.36		0.58		-1.70	***	-1.75	***
	(0.60)		(0.60)		(0.54)		(0.52)	
External availability	-0.54		0.07		0.95	*	0.81	
	(0.61)		(0.73)		(0.57)		(0.64)	
Volume	-1.18		-1.64		0.00		0.12	
	(1.51)		(1.53)		(0.73)		(0.75)	
Safety	0.24		0.46		-0.35		-0.40	
	(0.57)		(0.60)		(0.32)		(0.32)	
Production loss	2.36	***	2.83	***	0.88	*	0.77	
	(0.88)		(0.95)		(0.47)		(0.52)	
Scale up	0.89		0.74		0.68		0.72	
	(0.79)		(0.76)		(0.45)		(0.46)	
Speed	-1.61	*	-1.56	*	0.02		0.01	
	(0.93)		(0.93)		(0.59)		(0.59)	
Non-selection hazard			1.79	**			-0.43	
			(0.90)				(0.68)	
Constant	1.96		0.27		0.64		1.04	
	(3.31)		(3.46)		(1.55)		(1.62)	
F	3.03	***	3.57	***	3.37	***	3.13	***
N	203		203		203		203	
df_m	9		10		9		10	
Adj. R2	0.05		0.07		0.05		0.05	

Figure 4.7. OLS regressions of number of contacts[5]

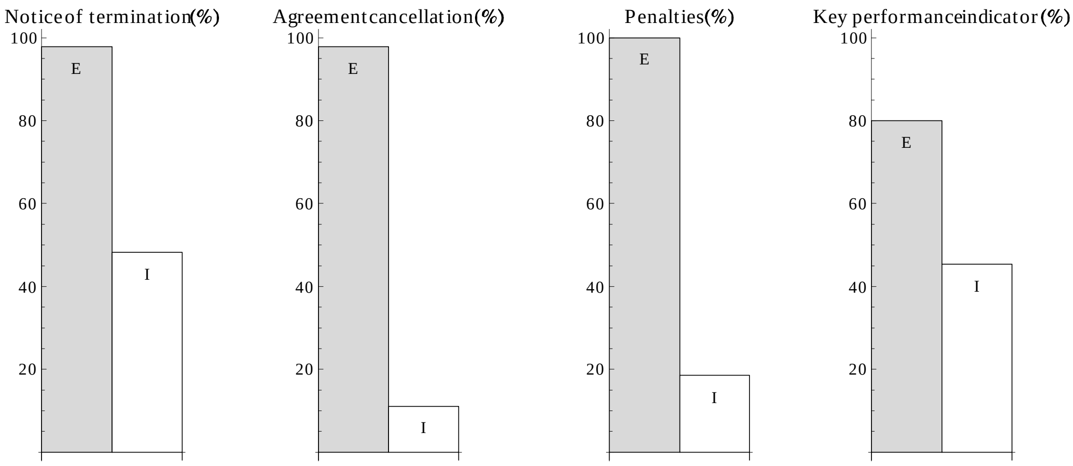

Figure 4.8. Percentage of external (E) and internal (I) agreements with incentive clauses

4.4.4. Incentive clauses

I capture four clauses that collectively provide an indication of the incentive intensity of an agreement: notice of termination, agreement cancellation, penalties, and key performance indicators. Figure 4.8 shows the sample averages per type of agreement for these clauses.

Notice of termination captures whether it is possible for one of the parties to cancel the contract without a specific reason. If the future of the relationship is not guaranteed but has to be earned (e.g. through good performance), then the incentive intensity is higher (see chapter 2). External agreements typically contain a notice of termination clause (98%). While a specific reason is not necessary, often such clauses specify the minimum required notification period to terminate the agreement (e.g. a couple of months). Only 48% of the internal agreements specify a notice of termination clause.

Agreement cancellation specifies the conditions under which an agreement may be cancelled. It differs from a notice of termination clause in that it requires a specific reason for agreement cancellation. Like notice of termination clauses, agreement cancellation clauses are included in most external agreements (98%). Agreement cancellation clauses are rare in internal agreements (11%). The findings on notice of termination and agreement cancellation are consistent with those in chapter 2. In chapter 2 I found that internal relationships were harder to terminate because they were mandated by top management, had lower variable costs than external relationships, and had stronger personal connections. Here I find an additional reason for why it is easier to terminate external relationships. Formal agreements explicitly leave open this option, even to the extent that no specific reason is necessary to break the external relationship.

Some form of penalties are included in all external agreements. Typically these clauses indicate that the supplier is responsible for achieving sufficient quality standards and is responsible for any damages if such standards are not met. The percentage of internal agreements with penalty clauses is much lower (19%).

Key performance indicators (or the intention to develop them) are included in 80% of the external agreements and in 45% of the internal agreements. Figure 4.9 provides a detailed examination of the difference between internal and external agreements and the usage of key performance indicators. The dependent variable in these models is a dummy variable which is one if and only if at least one key performance indicator is included. Models 1 and 2 are OLS regressions, where model 2 includes a non-selection hazard. Because of the discrete nature of the dependent variable, I also estimate a

	(1) OLS KPI		(2) OLS KPI		(3) probit KPI		(4) IV probit KPI	
Internal	-0.23	***	-0.56	***	-0.66	***	-1.58	***
	(0.08)		(0.16)		(0.22)		(0.35)	
Categories	0.03	**	0.01		0.09	*	0.05	
	(0.01)		(0.01)		(0.06)		(0.06)	
Knowledge specificity	-0.05		-0.02		-0.16		-0.06	
	(0.11)		(0.11)		(0.29)		(0.28)	
External availability	-0.16		-0.08		-0.42		-0.13	
	(0.11)		(0.12)		(0.29)		(0.30)	
Volume	0.24	**	0.17		0.69	**	0.44	
	(0.11)		(0.11)		(0.29)		(0.30)	
Safety	-0.09		-0.06		-0.26		-0.14	
	(0.07)		(0.07)		(0.19)		(0.19)	
Production loss	0.06		0.13		0.16		0.33	
	(0.09)		(0.09)		(0.24)		(0.24)	
Scale up	-0.08		-0.10		-0.23		-0.27	
	(0.08)		(0.07)		(0.23)		(0.22)	
Speed	-0.02		-0.02		-0.04		-0.02	
	(0.10)		(0.09)		(0.27)		(0.26)	
Non-selection hazard			0.24	**				
			(0.10)					
Constant	0.95	***	0.73	*	1.21		0.36	
	(0.37)		(0.37)		(0.96)		(0.98)	
F	6.34	***	6.51	***				
N	203		203		203		203	
df_m	9		10		9		9	
R2_adj	0.17		0.18					
Chi2					43.42	***	63.04	***

Figure 4.9. OLS and (IV)probit regressions of key performance indicators[6]

probit model (model 3) and an instrumental variable probit model (model 4). Model 4 uses an instrumental variable approach (with January as instrument) to correct for the possible endogeneity of internal.

The four models show consistent results: an external agreement is more likely to have a KPI clause than an internal agreement after controlling for transaction characteristics ($p < .01$ in all four models). The non-selection hazard is significant in model 2, which suggests that model 2 is preferred over model 1 because of the endogeneity of internal with respect to key performance indicators. None of the other control variables is significant in model 2. Model 2 has a good fit and an adjusted R^2 of 0.18. Similarly, the instrumental variable probit (model 4) has good fit, although none of the control variables are significant.

The results are consistent across the four incentive clauses (notice of termination, agreement cancellation, penalties, and key performance indicator). They are more

[6]* $p < .1$; ** $p < .05$; *** $p < .01$ in a two-tailed test. Robust standard errors for OLS and standard erros for (IV) probit are in parentheses below coefficients.

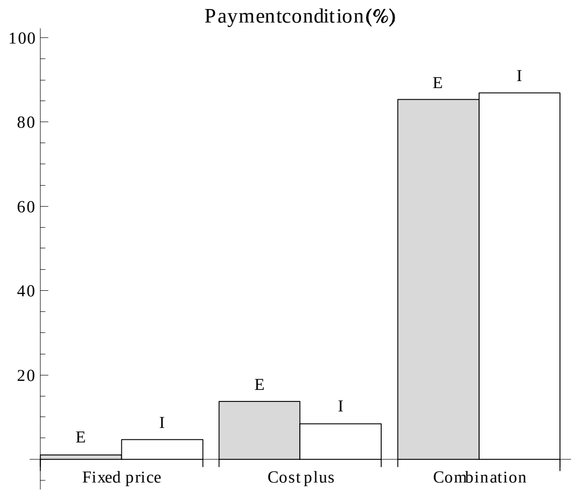

Figure 4.10. Percentage of external (E) and internal (I) agreements per payment condition

prevalent in external than internal agreements. Collectively, they suggest that incentive intensity is higher in external than internal relationships, a finding that is consistent with the finding in chapter 2.

4.4.5. Payment conditions

The payment conditions specified in agreements are fixed price, cost plus, or a combination of the two. Figure 4.10 shows the distribution of the payment conditions per agreement type. The results are similar for internal and external agreements. A χ^2-test cannot reject the hypothesis that the distributions are the same ($p = .17$). Few agreements have only a fixed price payment condition (between 1 and 5%). Possibly this is due to the nature of these maintenance services, which make it hard to specify ex-ante how much of the services are required in a given year and how much they would cost. The number of agreements with only cost plus provisions is slightly higher (between 8 and 14%). The payment to the supplier is based on the actual cost incurred (plus a margin). Most agreements are a combination of fixed price and cost plus (between 85 and 87%). In these agreements a fixed price is listed for those parts of the service that are easy to specify up-front, both in terms of the nature and the frequency of the service. Parts of the service that are harder to specify, or any additional work, is compensated on a cost plus basis.

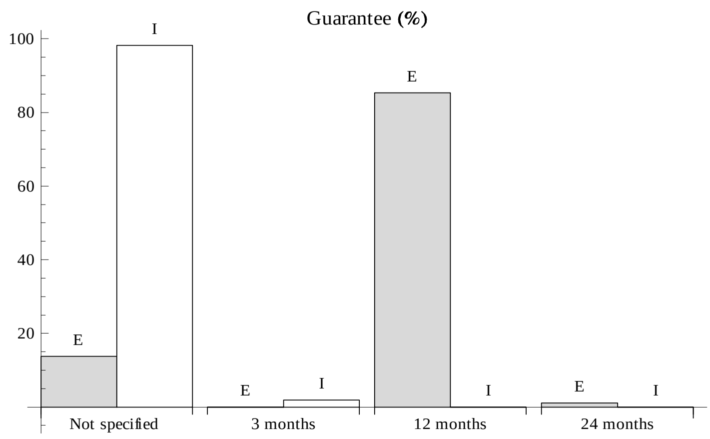

Figure 4.11. Percentage of external (E) and internal (I) agreements with a guarantee clause

4.4.6. Guarantee

Figure 4.11 shows the extent to which agreements make use of guarantee clauses, and if so the length of the guarantee period. About 14% of the external agreements specify no guarantee clause. The guarantee period for external agreements with a guarantee clause is typically 12 months (85% of total), and one agreement specifies a 24 month period. Most internal agreements do not mention guarantees (98%). Two internal agreements specify a guarantee period of three months.

4.4.7. Alternative parties

Two types of clauses in the contract regulate the role of alternative suppliers (see figure 4.12 for the presence of these per agreement type). The first, non-exclusive, captures whether the option of the buyer using alternative suppliers is explicitly ruled in. This clause is rare internally (2%) and quite common externally (65%). In the sample, no agreement has a clause formally specifying that the delivery of the service is exclusive to the supplier.

The second, subcontracting, specifies if a supplier can subcontract to another supplier. Such a clause is included in 88% of the external agreements and in 14% of the

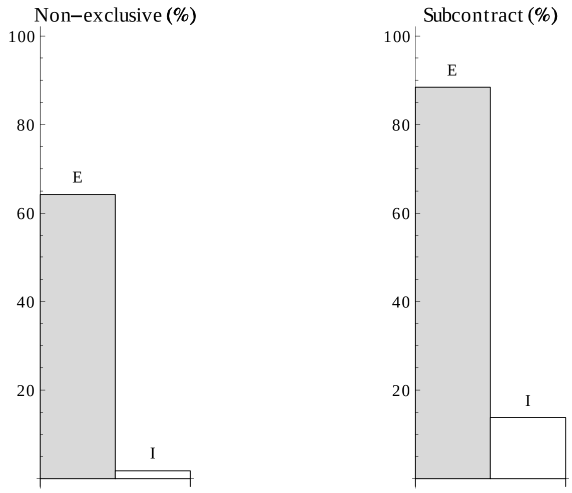

Figure 4.12. Percentage of external (E) and internal (I) agreements with clauses pertaining to alternative parties

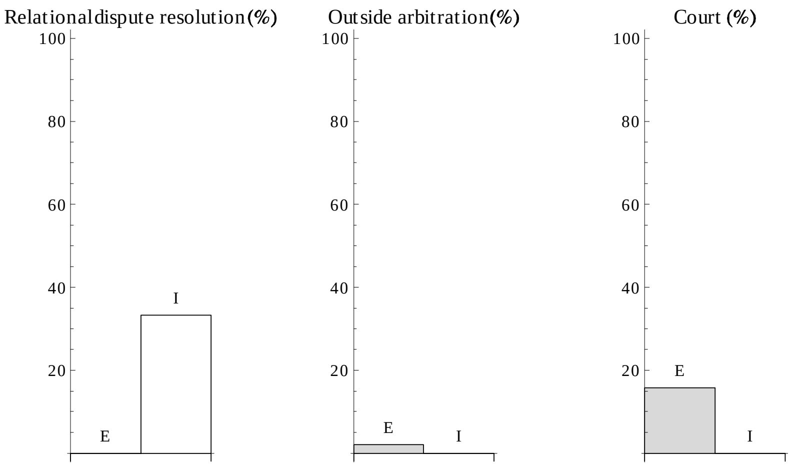

Figure 4.13. Percentage of external (E) and internal (I) agreements with clauses pertaining to dispute resolution

internal agreements. Typically, the main reason for including such a clause is to document that even if a subcontractor is used the main contractor is responsible. No agreement has a provision in which it is ruled out to use subcontractors.

4.4.8. Disputes

Three dependent variables capture whether an agreement specifies how to resolve a dispute: relational dispute resolution, outside arbitration, and court. Figure 4.13 shows the extent to which such clauses are present per agreement type. Relational dispute

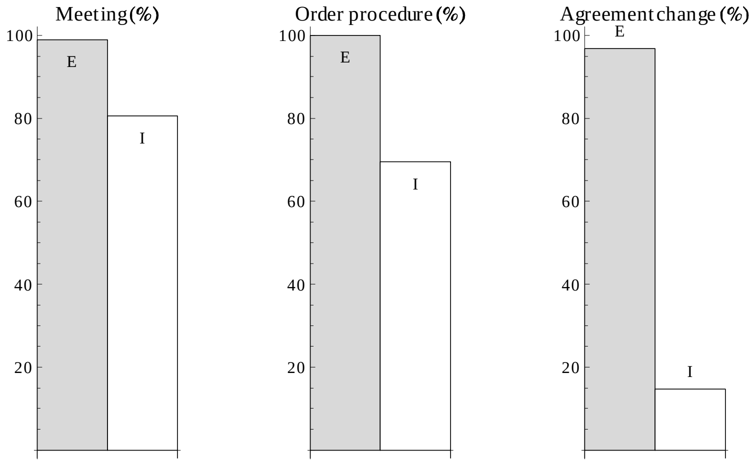

Figure 4.14. Percentage of external (E) and internal (I) agreements with a meeting, order procedure, and agreement change clause

resolution involves resolving disputes within the relationship without the involvement of outside parties. No external agreement explicitly specifies this possibility. In 33% of the internal agreements, some relational dispute resolution mechanism is specified. These dispute resolution mechanisms are often specified as hierarchical or escalation trees. If disputes cannot be resolved on lower levels, they are referred to higher levels. Interestingly, the highest level specified in the (internal) agreements is never a common boss to both parties. This finding resonates with the finding in chapter 2, where few if any disputes ever reached a common boss.

With outside arbitration a third party (but not a court) is used to help resolve disputes. This option is documented in two external agreements and in no internal agreements. The final dispute clause, court, indicates whether reference is made to legal action. This is never done internally. In 16% of the external agreements a clause related to courts is included.

These results suggest that in general little advanced planning on dispute resolution is present in agreements. In the instances in which it occurs, the focus is internally on resolution within the relationship and externally on resolution with the help of neutral outsiders.

	Where is there more of it?		
	External	Internal	No difference
Total pages	x		
Price pages	x		
Service pages			x
Buyer signatures			x
Supplier signatures		x	
Contacts buyer	x		
Contacts supplier			x
Notice of termination	x		
Agreement cancellation	x		
Penalties	x		
KPI	x		
Payment condition			x
Guarantee	x		
Non-exclusive	x		
Subcontract	x		
Rel. dispute resolution		x	
Outside arbitration			x
Court	x		
Meeting	x		
Order procedure	x		
Agreement change	x		

Figure 4.15. Summary of results

4.4.9. Other

Figure 4.14 shows the extent to which the last three clauses are present by agreement type. The first clause, meeting, documents how often the buyer and supplier hold meetings. About 81% of the internal agreements have a meeting clause, as do 98% of the external agreements. The second clause, order procedure, captures how a service request must be initiated. Such a clause is present in 100% of the external agreements. This is the case for 70% of the internal agreements. The third clause, agreement change, specifies how changes to the agreement can be made and formalized. Procedures for making changes to the agreement are included in 97% of the external agreements, but only in 15% of the internal agreements.

4.5. Discussion

Figure 4.15 provides an overview of the results. I discuss two of the main findings below.

4.5.1. Incentives

Based on the clauses in the agreements, incentives are stronger externally than internally. While the difference may not arise from payment conditions (as most internal and external agreements are a combination of fixed cost and cost plus), other clauses point in this direction. First, external agreements are more likely to have notice of termination and agreement cancellation clauses. These clauses specify that a contract can be terminated without reason or under reasons specified in the agreement. Together, these clauses make the continuation of the vertical relationship less guaranteed and more dependent on actions and performance. In chapter 2, I have shown how such a shadow of the future effect leads to stronger incentives if the future is not guaranteed.

Second, external agreements are more likely to have penalties and key performance indicators. More penalties and key performance indicators provide stronger incentives to perform in the external relationship. For both penalties and key performance indicators it is necessary to have monitoring systems to track performance in the relationship and compare it with standards agreed beforehand. It is interesting that transaction cost economics assumes that monitoring is more effective internally (Williamson, 1975), yet this data suggests that more monitoring related clauses are present in external agreements. Possibly it is the case that the costs of monitoring are higher externally, but so are the benefits. However, I cannot infer this from the data. More generally, it is not possible to predict whether the degree of cooperation is higher internally than externally because stronger incentives do not necessarily imply better aligned incentives.

4.5.2. The role of agreements

While prior research focused on how formal agreements can facilitate cooperation (e.g. Williamson, 1985; Grossman and Hart, 1986), recently it has been argued that formal agreements also have an important coordination role (Mayer and Argyres, 2004; Vanneste and Puranam, 2009). Cooperation is the alignment of incentives and coordination is the alignment of action. Both cooperation and coordination are necessary for any collaborative action, and neither is individually sufficient (Gulati et al., 2005).

Above I suggested that external agreements have more detail related to cooperation or incentive clauses. The issue is different for coordination clauses. I find that a lot of coordination details are captured in the maintenance service agreements, especially under service pages. For example, how often the service is required, when the service is needed, who is responsible, and how the service interacts with other processes. On average, an agreement has about eight pages of service information. Interestingly, internal agreements have the same number of service pages as external agreements (after controlling for transaction characteristics). This suggest that while internal agreements do not have a legal function, they are important devices to coordinate activities.

While the number service pages is similar for internal and external agreements, other coordination clauses like order procedure and meeting are more prevalent externally than internally. This invites some interesting speculation. Why are some of the non-legal clauses less specified internally than externally? A first possibility is that such provisions are not captured in the agreements I studied but in other documents. I have verified however that this is not the case. An alternative possibility is that such knowledge is present but uncodified, i.e. held as tacit knowledge by employees. Typically codification of such knowledge has two benefits. It enhances coordination by creating common knowledge among the exchange partners (Camerer and Knez, 1996). Codification also guards against organizational forgetting, for example due to employee turnover (Argote, 1999). If the costs of codification are low, then why would we not see codification? One explanation could be that the common ground is already high within firms because of frequent interactions and a shared history. Further research along the lines of Srikanth and Puranam (2007) and Puranam and Gulati (2008) is required to explore these issues.

4.6. Conclusion

To scholars of economic organization, firms and markets are the archetypical modes of governance. Firms and markets can be viewed as the opposite ends of a continuum of vertical relationships. Prior research has begun to analyze this continuum by arguing that market relationships are governed by formal agreements rather than by just a price mechanism. In this chapter, I build on this work and argue that relationships within firms can also be governed through formal agreements. While the legal implications of formal agreements are clearly different within firms (or even absent), I find that internal agreements have important incentive and coordination functions.

I analyze written agreements for maintenance services with internal and external suppliers from a Dutch production facility of a single company. I find that external agreements contain more incentive clauses, and internal and external agreements have a similar number of pages for describing the service and how the delivery of the service must be coordinated with other units and processes.

CHAPTER 5

Conclusion

In this dissertation I address the central question of how relationships between subsequent stages of a supply chain are different within than between firms. I focus explicitly on the role of incentives. Prior research has devoted significant time to understanding when subsequent stages are organized within a single firm and when between different firms. However, little research has directly explored how these alternatives are different. For this dissertation I have managed to find three settings in which I can directly and simultaneously observe elements of vertical relationships both within and between firms.

In chapter 2, I use interview data and a formal model. I study how the prospect of a future relationship affects incentives in the present, and how this differs within and between firms. The interview data is from respondents across eight multi-business unit companies in The Netherlands who are engaged in plural sourcing relationships. Plural sourcing relationships are relationships in which the same good is exchanged within and between firms. This ensures comparability of the transactions between the internal and external relationships. I find that: a) contrary to prior theory, cooperation is often higher in external than internal relationships, and b) it is harder to fire internal units than external units. In a formal model I show that finding b) is a sufficient explanation for finding a).

In chapter 3, I use comparative survey data on internal and external supplier relationships in the US automobile industry. I study how incentive intensity influences the attribution of trustworthiness to exchange partners. Because cooperation may arise from trust or incentives, the presence of strong incentives hampers the attribution of trustworthiness and development of trust. Partly based on my findings in the preceding chapter, I argue that incentive intensity is lower under vertical integration than non-integration. I predict that information arising from the relationship will be interpreted more positively under vertical integration than under non-integration (because of the higher incentives in the latter). Consistent with this prediction I find that: a) trust between exchange partners increases more with relationship duration under vertical integration than non-integration, and b) trust between exchange partners increases more with the extent to which employees of the partners are co-located under vertical integration than non-integration.

In chapter 4, my empirical setting is a Dutch production facility of a company active in the raw materials industry. I use their written agreements for maintenance services with internal and external suppliers. I combine this with the company's archival data on transaction and market characteristics. I study the extent to which the written agreements differ in internal and external relationships. I find that: a) external agreements contain more incentive clauses, and b) internal and external agreements have a similar number of pages for describing the service and how the delivery of the service must be coordinated with other units and processes.

In the following sections, I integrate the empirical findings across chapters and draw implications for theory and practice.

5.1. Main Findings

So how are relationships between subsequent stages of a supply chain different within than between firms? In this section I look at the empirical findings across chapters to provide answers to the main research question of the dissertation.

5.1.1. Relationship within firms are harder to terminate than between firms

In chapter 2, I find that internal relationships are harder to terminate because they are often mandated by top management, have lower variable costs than external relationships, and have stronger personal connections. In chapter 4, I find that in addition to these reasons, external relationships are easier to terminate than internal relationships because external agreements often explicitly specify the possibility to walk away from the relationship while internal agreements do not.

This difference has important consequences for the degree of cooperation within versus between firms. A stronger threat of termination in case of low performance provides stronger incentives to perform. If this threat is higher between firms than within firms, then one cannot automatically assume that incentive alignment is greater within than between firms as some theories do.

A stronger threat however is not always optimal. The downside of a strong threat is that a valuable relationship could be terminated after an incidental underperformance. I have begun to explore the situations under which a strong threat is optimal and when it is not. I find that technological uncertainty does not lead to unidirectional predictions. Further research is needed to explore the effect of technological uncertainty and other variables.

5.1.2. Dispute resolution within firms is not so different from dispute resolution between firms

In chapter 2, I find that disputes in relationships within firms infrequently, if at all, reach a common boss. As in external relationships, in internal relationships disputes are often resolved through escalation. However, such escalations rarely reach a common boss, because this boss is often multiple hierarchical layers removed from the origin of the dispute. In chapter 4, I find that dispute resolution procedures are documented in some internal agreements. These clauses specify the escalation chain. Interestingly, these chains never reach a boss who is common to both exchange partners. This reinforces the point that the role of a common boss in resolving disputes is less (or at least different) than assumed in prior theory. More generally, it suggests that internal dispute resolution is not so different from external dispute resolution, because a common boss may be so far away that it is practically the same as having no common boss.

5.1.3. Relationships between firms have stronger incentives than within firms

While this seems to be stating the painfully obvious, the findings are more subtle. In chapter 2, I find that the prospect of a joint future has a stronger incentive effect between than within firms because of the extent to which the joint future is guaranteed. In chapter 4, I find that external agreements contain more incentive clauses than internal agreements. Finally, while I do not measure incentives directly in chapter 3, I find that the attributions of trust to exchange partners are consistent with a theory that assumes stronger incentives between than within firms.

Prior theory reaches the same conclusions, but invokes a different mechanism. Incentive differences are based on residual claimancy, i.e. the right to keep the remaining value. In a direct test of this proposition, I find that this is not the case. In the internal and external agreements analyzed in chapter 4, I find that internal and external suppliers are compensated in a similar way (fixed price, cost plus, or a combination of the two). Possibly this lack of difference can entirely be ascribed to the setting, i.e. maintenance services of which the requirements can be hard to predict. Even if this is the case, then it is not clear that the argument of residual claimancy can explain differences in the incentives of individuals, who are ultimately the ones who act. In the chapter 2, I find that employees of an internal division, like employees from an external unit, are usually not residual claimants. Both are employees and not owners. Therefore, the incentives to behave opportunistically may not be very different for an employee from an external unit than for one from an internal unit.

5.1.4. Relationships within firms have higher tolerance than between firms

In chapter 2, I find that internal relationships have a higher tolerance for poor performance than external relationships. In chapter 3, I find that internal relationships have a higher tolerance for risk when classifying an exchange partner as trustworthy. In chapter 4, I find that internal relationships have a higher tolerance for leaving aspects of the exchange unspecified than external relationships. While collectively these findings point to an intriguing difference between internal and external relationships, further research is needed to clarify under which situations the need for tolerance is high (and internal relationships are preferred).

5.2. Implications for Theory

In this section, I highlight three areas to which this dissertation makes contributions.

5.2.1. Theories of the firm

Many theories of the firm exist (Alchian and Demsetz, 1972; Williamson, 1975, 1985; Grossman and Hart, 1986; Hart and Moore, 1990; Holmström and Milgrom, 1991; Holmström, 1999; Gibbons, 2005). These theories share two sets of premises. First, contracts are incomplete. It is not possible to ex-ante specify a full set of rules for how to conduct an exchange. This is because actions or outcomes are difficult to measure (Alchian and Demsetz, 1972), people are boundedly rational (Williamson, 1975), or it is extremely costly to specify all possible contingencies (Grossman and Hart, 1986). As a consequence, some incentive conflict between exchange partners cannot be resolved through agreements. Second, integration is a useful way to align incentives. Incentive alignment is achieved through decision and payment rights (Alchian and Demsetz, 1972; Williamson, 1975, 1985; Grossman and Hart, 1986; Hart and Moore, 1990; Holmström and Milgrom, 1991; Holmström, 1999). If the benefits of increased incentive alignment outweigh the costs of organizing, then integration is the preferred governance mode.

In this dissertation, I show that the potential value of future business is an important means to align incentives between exchange partners. Because external relationships are less guaranteed than internal relationships, the shadow of the future is a stronger force externally than internally. In direct contrast to prior theory, this mechanism suggests stronger incentive alignment externally than internally. The shadow of the future is especially an important force when decisions and agreements cannot be fully specified ex-ante. This is exactly the domain of the theories of the firm. Therefore, real progress will come from extending theories of the firm with this new suggested mechanism.

The most influential paper in the domain of the theory of the firm and future business is Baker et al. (2002). They use asset ownership as the distinguishing feature between integration and non-integration. I find that for a big empirical class of vertical relationships within firms no exchange partner owns the assets of the other. Therefore, I cannot use their model to capture the trade-offs in these relationships. Instead, based on my field observations I define integration as a reduced probability that a relationship will be terminated given low performance. This is equivalent to a trigger strategy with varying levels of forgiveness (whereas Baker et al. (2002) consider only pure trigger strategies). This refines Baker et al. (2002) who suggest that vertical integration affects the parties' willingness to use outside options by making a simpler but perhaps more fundamental point: vertical integration may often simply rule out any outside options.

To make progress in the theory of the firm domain, I suggest three avenues for future research. First, further work is needed to generate empirical predictions about the location of firm boundaries based on the shadow of the future. In chapter 2, I distinguish between the incentive effect (the additional effort put in to prevent relationship termination due to low performance) and the termination effect (the loss in value should a relationship be terminated). In future work, I will explore when and how these effects vary.

Second, this theory based on the shadow of the future should be contrasted with existing theories of the firm. This is important because the theories conceptions of the firm and its role in the wider economy are different. In the existing theories, a firm exists to facilitate cooperation. In the proposed theory, a firm provides a forgiving environment useful for experimentation and complex transactions. In comparing different theories, we should focus on situations where theories lead to different predictions to understand their relative merit (Stinchcombe, 1968). The step above is a necessary precondition.

Third, we should not only explore areas in which the theories differ but also areas where they reinforce each other. For example, how do shadow of the future arguments impact transaction costs? No single theory can explain everything and value may come from integrating different theories. A particularly useful area for integration is the distinction between incentive alignment and incentive intensity. Incentive alignment is the extent to which exchange partners want to do the same thing. Incentive intensity is the extent to which exchange partners are motivated to do anything. For example, consider two tasks and an upstream and downstream party. Task A adds value for downstream and task B does not add value for downstream (but could for upstream). Incentives are aligned if upstream wants to work on task A but not on B. Incentives are intensive if upstream is strongly rewarded for a given task (whether it is A or B). All theories rely on either incentive intensity or alignment, and some theories on both. A clear distinction between the two will facilitate the comparison and integration of different theories of the firm.

5.2.2. Trust and governance

Economic sociology and transaction costs economics are the dominant theoretical perspectives on trust in vertical relationships. Economic sociology argues and finds that there can be a lot of trust between firms (Granovetter, 1985; Uzzi, 1997). Transaction cost economists argue about, but do not measure, differences in trust (or more precisely opportunism) within versus between firms (Williamson, 1975, 1985). In this dissertation, I advance these perspectives by comparing levels and drivers of trust within and between firms. I find that, on average, the level of trust between exchange partners is the same within as between firms. I also find that because of stronger incentives in external relationships, trust develops slower externally than internally.

These findings suggest that the debate on whether trust is higher internally or externally (Williamson, 1975; Granovetter, 1985) overlooks two important aspects: time and selection. First, because trust develops faster over time internally than externally, it is more likely that trust is higher internally than externally for older relationships.

Second, because I find that for a relationship with an average duration trust is the same for internal and external partners, it means that trust was higher in external partners when they were selected than trust in internal partners at the beginning of the relationship. Because the selection of potential external partners is often greater than the number of internal partners, this finding may well generalize beyond the current setting (assuming similar trust distributions internally and externally).

The slower trust development has been referred to as a crowding out effect - the presence of strong incentives inhibits trust attributions (Puranam and Vanneste, 2009). This dissertation advances earlier work on crowding out effects (e.g. Molm et al. (2000); Malhotra and Murnighan (2002)) in two ways. First, to my knowledge this is the first attempt to test crowding out effects in a field setting. Prior work has relied exclusively on laboratory experiments. Second, whereas prior research focused on relationships between two individuals, I explore crowding out in relationships between organizational units.

When moving up a unit of analysis from the individual to the group level, the distinction between vertical and authority relationships is important. In this dissertation, I define a vertical relationship as a relationship between two subsequent stages of a value chain. An authority relationship is when one party has a decision right over the other, for example a boss and an employee (see chapter 1). For example, Ghoshal and Moran (1996) argue that fiat or hierarchical control may lead to lower trust because the act of supervising can be seen as distrusting. To the extent that external relationships rely less on fiat and hierarchical control, it suggests more trust in external than internal relationships. However, Ghoshal and Moran (1996) describe trust in authority relationships, whereas my empirical setting is vertical relationships. Future work in this area should be careful to make the distinction between the two.

This study also has interesting implications for the debate about trust and the degree of calculativeness (Shapiro et al., 1992; Williamson, 1993; Mayer et al., 1995; Lewicki and Bunker, 1996). The core of the debate is whether trust is different from the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor *because* the other party is incentivized to act cooperatively (i.e. "calculative trust"). The findings suggest that actors in vertical exchange relationships indeed perceive these as different. If they had not distinguished between the two, then we would have found no differences in speed of trust development.

At the same time, it is interesting to note that all the arguments I put forward about attributions of outcomes and inferring trustworthiness are completely consistent with a rational Bayesian updating or a calculative approach. How can we reconcile this with the debate on calculativeness and trust? One way to resolve this paradox is to realize the difference between the "calculative decision to be trustworthy" and the "calculative decision to trust". While the first seems to be a contradiction in terms, the second seems perfectly plausible. In ongoing and related work I am developing these arguments further.

5.2.3. Shadow of the future

The study of cooperation has long recognized that even if cooperation is not optimal in the short run, it may be so in the long run (Kreps et al., 1982; Axelrod, 1984; Fudenberg and Maskin, 1986). The basic intuition is that future interactions represent potential value. The value created in a relationship is higher if exchange partners cooperate than if they do not. As the shadow of the future grows longer, the payoffs from cooperation relative to non-cooperation increase. As a result, the incentive to cooperate goes up. Empirical work provides support for this intuition. In prisoner's dilemma games, people cooperate more as the expectation of future interaction increases (Roth and Murnighan, 1978; Murnighan and Roth, 1983; Bo, 2005). The key insight from this literature is that cooperation increases as the shadow of the future exogenously increases.

In this dissertation, I expand these theories and argue that cooperation increases even more as the shadow of the future *endogenously* increases. With endogenous increases, I mean that the duration of the relationship is made contingent on prior cooperation. In prior experimental work on games, the expectation of future interactions is the key treatment. This is operationalized as the expected number of rounds the game will continue. Subjects are randomly assigned to a level of expected future interactions, independent of their prior cooperative history (Roth and Murnighan, 1978; Murnighan and Roth, 1983; Bo, 2005). The shadow of the future is exogenous to prior decisions.

In my field setting, I find that in vertical relationships the decision to continue is based on prior cooperation. The shadow of the future is endogenously determined. I distinguish between p, the probability that the relationship is terminated given bad performance, and δ, the discount factor or the value that participants place on future income. Prior work on the shadow of the future has focused on the discount factor. I show that the probability of continuation is also important and can result in significant cooperation differences in field settings.

Future research could further explore the role of the probability of continuation. An interesting area of research is to understand what influences this probability. In this dissertation, I highlight firm boundaries as an important driver. Future work could explore other drivers and investigate how much this probability is a given in a relationship versus how much participants influence this probability.

5.3. Implications for Practice

The findings have the following implications for practice. First, vertical integration should *not* be chosen because it guarantees more cooperation than non-integration, because it does not. If a joint future is sufficiently important for both parties, then non-integration may achieve higher levels of cooperation than vertical integration. A key distinction between integration and non-integration is the extent to which future business is guaranteed. Typically, a relationship within a firm comes with the implicit or explicit understanding that they will continue into the future. Continuation is only weakly related to the performance of the relationship. The continuation decision for a relationship between firms is much more contingent on good performance of the relationship.

A key trade-off for managers in choosing between integration and non-integration is between the incentive effect and the termination effect. Because under non-integration there is always a threat that the relationship will be terminated if performance is not satisfactory, exchange partners are strongly incentivized to put in their best effort (i.e. the incentive effect). The downside is that a relationship could be terminated prematurely and a lot of potential value is lost (i.e. the termination effect). If the need for strong incentives is high, then non-integration seems preferable. However, if the risk of loosing a valuable relationship is too great, integration seems preferable.

Second, nothing prevents trust from being developed between firms to the same extent as within firms, it may only take a bit longer. This is due to the stronger incentives surrounding the exchange between firms, which makes it difficult to infer trustworthy behavior from cooperation. The key point, however, is that to the extent that trust is an important factor when deciding between integration and non-integration, integration is not uniformly preferred over non-integration. Rather, the comparison should be between trust in a specific internal relationship and trust in a specific external relationship. The variation in trust is greater within each procurement mode than between.

Another interesting finding is that repeated interactions do not necessarily lead to increased trust. An explanation is that through close interactions an exchange partner may actually discover that the other is untrustworthy, leading to reduced trust in the relationship. The empirical implication is that to build trust in vertical relationships spending time together is not sufficient.

Third, while formal agreements have no legal role internally, they offer an important means for coordination within firms. Written agreements capture who should do what and when. They facilitate the efficient alignment of actions. This role of agreements is different from that of ensuring cooperation - the alignment of incentives. Coordination and cooperation are both necessary for working together in vertical relationships, and neither of them is sufficient by itself. Similarly, formal agreements not only provide incentive alignment for exchange partners between firms, but also align the actions of partners. Whereas traditionally the focus has been on how agreements can protect exchange partners from opportunistic behavior, agreements are also an important device for planning the exchange.

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APPENDIX A

Proofs for Chapter 2

A.1. Boundary conditions

Because and $U^O = u^O + \delta u^O + \delta^2 u^O + ... = \frac{u^O}{1-\delta}$ and hence $D^O = \frac{d^O}{1-\delta}$, boundary condition 2.1 is:

$$\begin{aligned}
U^R[e,p,\alpha,\gamma] &> U^O \\
\frac{w+(\gamma+q[e,\alpha])b_H+(1-\gamma-q[e,\alpha])\big((1-p)b_L+p\delta U^O\big)-c[e]}{1-\delta+(1-\gamma-q[e,\alpha])p\delta} &> U^O \\
w+(\gamma+q[e,\alpha])\,b_H+(1-\gamma-q[e,\alpha])\,(1-p)\,b_L &> (1-\delta)\,U^O+c[e] \\
w+(\gamma+q[e,\alpha])\,b_H+(1-\gamma-q[e,\alpha])\,(1-p)\,b_L &> u^O+c[e]
\end{aligned} \tag{A.1}$$

Boundary condition 2.2 is:

$$\begin{aligned}
D^R[e,p,\alpha,\gamma] &> D^O \\
\frac{Q_L+(\gamma+q[e,\alpha])(\Delta Q-b_H)+(1-\gamma-q[e,\alpha])\big(p\delta D^O-(1-p)b_L\big)-w}{1-\delta+(1-\gamma-q[e,\alpha])p\delta} &> D^O \\
w+(\gamma+q[e,\alpha])\,b_H+(1-\gamma-q[e,\alpha])\,(1-p)\,b_L &< Q_L+(\gamma+q[e,\alpha])\,\Delta Q-(1-\delta)\,D^O \\
w+(\gamma+q[e,\alpha])\,b_H+(1-\gamma-q[e,\alpha])\,(1-p)\,b_L &< Q_L+(\gamma+q[e,\alpha])\,\Delta Q-d^O
\end{aligned} \tag{A.2}$$

Combining A.1 and A.2 we get the following constraints for the fixed fee and bonuses:

$$u^O+c[e] < w+(\gamma+q[e,\alpha])\,b_H+(1-\gamma-q[e,\alpha])\,(1-p)\,b_L < Q_L+(\gamma+q[e,\alpha])\,\Delta Q-d^O$$

A.2. Optimal effort

From the implicit function theorem:

$$\frac{\partial e^*}{\partial p} = -\frac{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p}}{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}} \tag{A.3}$$

$$\frac{\partial e^*}{\partial \alpha} = -\frac{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \alpha}}{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}} \tag{A.4}$$

$$\frac{\partial e^*}{\partial \gamma} = -\frac{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \gamma}}{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}} \tag{A.5}$$

Because $\frac{\partial F^1[e;p,\alpha]}{\partial e} < 0$ from the second order condition 2.5, it follows that $\frac{\partial e^*}{\partial p}$ has the same sign as $\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p}$, $\frac{\partial e^*}{\partial \alpha}$ as $\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \alpha}$, and $\frac{\partial e^*}{\partial \gamma}$ as $\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \gamma}$.

Proposition 1: $\frac{\partial e^*}{\partial p} > 0$. We need to show that $\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p} > 0$.

$$\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p} = \frac{\partial q[e,\alpha]}{\partial e}\left(b_L + \delta\left(U^R[e,p,\alpha,\gamma] - U^O\right) + p\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}\right) \tag{A.6}$$

We require $\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}$:

$$\begin{aligned}\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p} &= -\left(1-\gamma-q[e,\alpha]\right)\left(b_L + \delta\left(U^R[e,p,\alpha,\gamma] - U^O\right)\right) \\ &\quad + \left(1-\left(1-\gamma-q[e,\alpha]\right)p\right)\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p} \\ &= -\frac{(1-\gamma-q[e,\alpha])\left(b_L+\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)}{1-\delta+(1-\gamma-q[e,\alpha])p\delta} \qquad \text{(A.7)}\end{aligned}$$

Substituting A.7 in A.6 gives:

$$\begin{aligned}\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p} &= \frac{\partial q[e,\alpha]}{\partial e}\Big(b_L + \delta\left(U^R[e,p,\alpha,\gamma] - U^O\right) \\ &\quad -p\delta\frac{(1-\gamma-q[e,\alpha])\left(b_L+\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)}{1-\delta+(1-\gamma-q[e,\alpha])p\delta}\Big) \\ &= \frac{\partial q[e,\alpha]}{\partial e}\frac{(1-\delta)\left(b_L+\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)}{1-\delta+(1-\gamma-q[e,\alpha])p\delta} > 0 \qquad \text{(A.8)}\end{aligned}$$

Because $1-\delta > 0$ and $U^R[e,p,\alpha,\gamma] > U^O$ (from 2.1), $\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p} > 0$ and by implication $\frac{\partial e^*}{\partial p} > 0$.

Proposition 2: $\frac{\partial e^*}{\partial \alpha} > 0$. We need to show that $\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \alpha} > 0$.

$$\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \alpha} = \frac{\partial^2 q[e,\alpha]}{\partial e \partial \alpha}\left(b_H - (1-p)\,b_L + p\delta\left(U^R[e,p,\alpha,\gamma] - U^O\right)\right) + \frac{\partial q[e,\alpha]}{\partial e} p\delta \frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \alpha} \tag{A.9}$$

We require $\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \alpha}$:

$$\begin{aligned}\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \alpha} &= \frac{\partial q[e,\alpha]}{\partial \alpha}\left(b_H - (1-p)\,b_L + p\delta\left(U^R[e,p,\alpha,\gamma] - U^O\right)\right) \\ &\quad + \left(1 - \left(1-\gamma-q[e,\alpha]\right)p\right)\delta \frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \alpha} \\ &= \frac{\frac{\partial q[e,\alpha]}{\partial \alpha}\left(b_H-(1-p)b_L+p\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)}{1-\delta+(1-\gamma-q[e,\alpha])p\delta} \qquad \text{(A.10)}\end{aligned}$$

Substituting A.10 in A.9 gives:

$$\begin{aligned}\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \alpha} &= \frac{\partial^2 q[e,\alpha]}{\partial e \partial \alpha}\left(b_H - (1-p)\,b_L + p\delta\left(U^R[e,p,\alpha,\gamma] - U^O\right)\right) \\ &\quad + \frac{\partial q[e,\alpha]}{\partial e} p\delta \left(\frac{\frac{\partial q[e,\alpha]}{\partial \alpha}\left(b_H-(1-p)b_L+p\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)}{1-\delta+(1-\gamma-q[e,\alpha])p\delta}\right) \\ \text{(A.11)} &= \left(\frac{\partial^2 q[e,\alpha]}{\partial e \partial \alpha} + \frac{\frac{\partial q[e,\alpha]}{\partial e} p\delta \frac{\partial q[e,\alpha]}{\partial \alpha}}{1-\delta+(1-\gamma-q[e,\alpha])p\delta}\right)\left(b_H - (1-p)\,b_L + p\delta\left(U^R[e,p,\alpha,\gamma] - U^O\right)\right) \\ &> 0\end{aligned}$$

Because $b_L \leq b_H$, $U^R[e,p,\alpha,\gamma] > U^O$ (from 2.1), and by definition $\frac{\partial^2 q[e,\alpha]}{\partial e \partial \alpha}, \frac{\partial q[e,\alpha]}{\partial \alpha} > 0$, so that $\frac{\partial F^1[e;p,\alpha]}{\partial \alpha} > 0$ and by implication $\frac{\partial e^*}{\partial \alpha} > 0$.

Proposition 3: $\frac{\partial e^*}{\partial \gamma} > 0$. We need to show that $\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \gamma} > 0$.

$$\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \gamma} = \frac{\partial q[e,\alpha]}{\partial e} p\delta \frac{\partial U^R[e,p,\alpha]}{\partial \gamma} \tag{A.12}$$

We require $\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \gamma}$:

$$\begin{aligned}\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \gamma} &= b_H - (1-p)\,b_L + p\delta\left(U^R[e,p,\alpha] - U^O\right) \\ &\quad + \left(1 - \left(1-\gamma-q[e,\alpha]\right)p\right)\delta \frac{\partial U^R[e,p,\alpha]}{\partial \gamma} \\ &= \frac{b_H-(1-p)b_L+p\delta\left(U^R[e,p,\alpha]-U^O\right)}{1-(1-(1-\gamma-q[e,\alpha])p)\delta} \qquad \text{(A.13)}\end{aligned}$$

Substituting A.13 in A.12 gives:

$$\text{(A.14)}\qquad \frac{\partial F^1[e;p,\alpha,\gamma]}{\partial\gamma} = \frac{\partial q[e,\alpha]}{\partial e}p\delta\frac{b_H-(1-p)b_L+p\delta\left(U^R[e,p,\alpha]-U^O\right)}{1-(1-(1-\gamma-q[e,\alpha])p)\delta} > 0$$

Because $b_L \leq b_H$, $U^R[e,p,\alpha,\gamma] > U^O$ (from 2.1), $\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial\gamma} > 0$ and by implication $\frac{\partial e^*}{\partial\gamma} > 0$.

A.3. Optimal threat level

From the implicit function theorem:

$$\text{(A.15)}\qquad \frac{\partial p^*}{\partial\alpha} = -\frac{\frac{\partial F^2[p;\alpha,\gamma]}{\partial\alpha}}{\frac{\partial F^2[p;\alpha,\gamma]}{\partial p}}$$

$$\text{(A.16)}\qquad \frac{\partial p^*}{\partial\gamma} = -\frac{\frac{\partial F^2[p;\alpha,\gamma]}{\partial\gamma}}{\frac{\partial F^2[p;\alpha,\gamma]}{\partial p}}$$

Because $\frac{\partial F^2[p;\alpha,\gamma]}{\partial p} < 0$ from the second order condition 2.7, it follows that $\frac{\partial p^*}{\partial\alpha}$ has the same sign as $\frac{\partial F^2[p;\alpha,\gamma]}{\partial\alpha}$, and $\frac{\partial p^*}{\partial\gamma}$ as $\frac{\partial F^2[p;\alpha,\gamma]}{\partial\gamma}$. To determine the sign of these, we need:

$$\begin{aligned}
\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} &= \frac{\partial q[e^*,\alpha]}{\partial e^*}\left(\Delta Q + p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right) - \frac{\partial c[e^*]}{\partial e^*} \\
&\quad + \left(1-\left(1-\gamma-q[e^*,\alpha]\right)p\right)\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} \\
\text{(A.17)}\qquad &= \frac{\frac{\partial q[e^*,\alpha]}{\partial e^*}\left(\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right)-\frac{\partial c[e^*]}{\partial e^*}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta} > 0 \\
\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial p} &= -\left(1-\gamma-q[e^*,\alpha]\right)\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right) \\
&\quad + \left(1-\left(1-\gamma-q[e^*,\alpha]\right)p\right)\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial p} \\
\text{(A.18)}\qquad &= -\frac{(1-\gamma-q[e^*,\alpha])\delta\left(S^R[e^*,p,\alpha]-S^O\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta} < 0 \\
\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\alpha} &= \frac{\partial q[e^*,\alpha]}{\partial\alpha}\left(\Delta Q + p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right) \\
&\quad + \left(1-\left(1-\gamma-q[e^*,\alpha]\right)p\right)\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\alpha} \\
\text{(A.19)}\qquad &= \frac{\frac{\partial q[e^*,\alpha]}{\partial\alpha}\left(\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta} > 0
\end{aligned}$$

$$\begin{aligned}
\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial \gamma} &= \Delta Q + p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right) \\
&\quad + \left(1-\left(1-\gamma-q[e^*,\alpha]\right)p\right)\tfrac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial \gamma} \\
&= \tfrac{\Delta Q + p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta} > 0 \qquad \text{(A.20)}
\end{aligned}$$

A.3.1. Generic functional forms

A.3.1.1. Controllability of task. For $\frac{\partial p^*}{\partial \alpha}$ we need to determine the sign of:

$$\begin{aligned}
\frac{\partial F^2[p;\alpha,\gamma]}{\partial \alpha} &= \tfrac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \alpha} + \left(\tfrac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \alpha} + \tfrac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\tfrac{\partial e^*}{\partial \alpha}\right)\tfrac{\partial e^*}{\partial p} \\
&\quad + \tfrac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\tfrac{\partial^2 e^*}{\partial p \partial \alpha}
\end{aligned}$$

Above we have established the following:

$$\begin{aligned}
\frac{\partial e^*}{\partial \alpha} &> 0 \\
\frac{\partial e^*}{\partial p} &> 0 \\
\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} &> 0
\end{aligned}$$

I explore the other components below.

$$\begin{aligned}
\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \alpha} &= \tfrac{\partial q[e^*,\alpha]}{\partial \alpha}\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O+p\tfrac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial p}\right) \\
&\quad - \left(1-\gamma-q[e^*,\alpha]\right)\delta\tfrac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial \alpha} \\
&\quad + \left(1-\left(1-\gamma-q[e^*,\alpha]\right)p\right)\delta\tfrac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \alpha} \\
&= \tfrac{\frac{\partial q[e^*,\alpha]}{\partial \alpha}\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O+p\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial p}\right)-(1-\gamma-q[e^*,\alpha])\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial \alpha}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta} \qquad \text{(A.21)}
\end{aligned}$$

Substituting A.18 and A.19 in A.21 gives:

$$\begin{aligned}\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p\partial\alpha} &= \frac{\frac{\partial q[e^*,\alpha]}{\partial\alpha}\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O-p\frac{(1-\gamma-q[e^*,\alpha])\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}\\ &\quad -\frac{(1-\gamma-q[e^*,\alpha])\delta\frac{\frac{\partial q[e^*,\alpha]}{\partial\alpha}\left(\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}\\ &= \frac{\frac{\partial q[e^*,\alpha]}{\partial\alpha}\delta\left((1-\delta-(1-\gamma-q[e^*,\alpha])p\delta)\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)-(1-\gamma-q[e^*,\alpha])\Delta Q\right)}{(1-\delta+(1-\gamma-q[e^*,\alpha])p\delta)^2}\end{aligned}$$

From this we can determine when this expression is negative:

$$\begin{aligned}\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p\partial\alpha} &< 0 \text{ i.f.f.}\\ (1-\delta-(1-\gamma-q[e^*,\alpha])p\delta)\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)-(1-\gamma-q[e^*,\alpha])\Delta Q &< 0\\ \left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]}-p\delta\right)\left(S^R[e^*,p,\alpha,\gamma]-S^O\right) &< \Delta Q \qquad \text{(A.22)}\end{aligned}$$

The next component is:

$$\begin{aligned}\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial\alpha} &= \frac{\partial^2 q[e^*,\alpha]}{\partial e^*\partial\alpha}\left(\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right)+\frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\alpha}\\ &\quad +\frac{\partial q[e^*,\alpha]}{\partial\alpha}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}+(1-(1-\gamma-q[e^*,\alpha])p)\delta\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial\alpha}\\ \text{(A.23)} &= \frac{\frac{\partial^2 q[e^*,\alpha]}{\partial e^*\partial\alpha}\left(\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right)+\frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\alpha}+\frac{\partial q[e^*,\alpha]}{\partial\alpha}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta} > 0\end{aligned}$$

The next component is:

$$\begin{aligned}\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2} &= \frac{\partial^2 q[e^*,\alpha]}{\partial (e^*)^2}\left(\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right)+2\frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\\ &\quad -\frac{\partial^2 c[e^*]}{\partial (e^*)^2}+(1-(1-\gamma-q[e^*,\alpha])p)\delta\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\\ \text{(A.24)} \quad &= \frac{\frac{\partial^2 q[e^*,\alpha]}{\partial (e^*)^2}\left(\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right)+2\frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}-\frac{\partial^2 c[e^*]}{\partial (e^*)^2}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}\end{aligned}$$

Substituting A.17 in A.24 gives:

$$\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial\left(e^*\right)^2} = \frac{1}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta} * \left(\frac{\partial^2 q[e^*,\alpha]}{\partial(e^*)^2}\left(\Delta Q + p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right) + 2\frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\frac{\partial q[e^*,\alpha]}{\partial e^*}\left(\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right)-\frac{\partial c[e^*]}{\partial e^*}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta} - \frac{\partial^2 c[e^*]}{\partial(e^*)^2}\right)$$

Hence, the sign of $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial(e^*)^2}$ depends on the relative strength of $\frac{\partial^2 q[e^*,\alpha]}{\partial(e^*)^2}$ and $\frac{\partial^2 c[e^*]}{\partial(e^*)^2}$ versus $\frac{\partial q[e^*,\alpha]}{\partial e^*}$. Without further restrictions on their relative strength, the sign of $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial(e^*)^2}$ is indeterminate. For the final component, $\frac{\partial^2 e^*}{\partial p\partial\alpha}$, we can make use of $\frac{\partial e^*}{\partial p} = -\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p} / \frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}$ (from A.3):

$$\begin{aligned}
\frac{\partial^2 e^*}{\partial p\partial\alpha} &= -\frac{\partial\left(\frac{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p}}{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}}\right)}{\partial\alpha} - \frac{\partial\left(\frac{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p}}{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}}\right)}{\partial e}\frac{\partial e^*}{\partial\alpha} \\
&= -\frac{\frac{\partial F^1}{\partial e}\frac{\partial^2 F^1}{\partial p\partial\alpha} - \frac{\partial F^1}{\partial p}\frac{\partial^2 F^1}{\partial e\partial\alpha}}{\left(\frac{\partial F^1}{\partial e}\right)^2} - \frac{\frac{\partial F^1}{\partial e}\frac{\partial^2 F^1}{\partial p\partial e} - \frac{\partial F^1}{\partial p}\frac{\partial^2 F^1}{(\partial e)^2}}{\left(\frac{\partial F^1}{\partial e}\right)^2}\frac{\partial e^*}{\partial\alpha} \\
&= -\frac{\frac{\partial^2 F^1}{\partial p\partial\alpha} + \frac{\partial e^*}{\partial p}\frac{\partial^2 F^1}{\partial e\partial\alpha}}{\frac{\partial F^1}{\partial e}} - \frac{\frac{\partial^2 F^1}{\partial p\partial e} + \frac{\partial e^*}{\partial p}\frac{\partial^2 F^1}{(\partial e)^2}}{\frac{\partial F^1}{\partial e}}\frac{\partial e^*}{\partial\alpha}
\end{aligned}$$

Above we have established the following:

$$\begin{aligned}
\frac{\partial e^*}{\partial p} &> 0 \\
\frac{\partial e^*}{\partial\alpha} &> 0 \\
\frac{\partial F^1}{\partial e} &< 0
\end{aligned}$$

For the others:

$$\begin{aligned}
\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial p\partial\alpha} &= \frac{\partial^2 q[e,\alpha]}{\partial e\partial\alpha}\left(b_L + \delta\left(U^R[e,p,\alpha,\gamma]-U^O\right) + p\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}\right) \\
&\quad + \frac{\partial q[e,\alpha]}{\partial e}\left(\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial\alpha} + p\delta\frac{\partial^2 U^R[e,p,\alpha,\gamma]}{\partial p\partial\alpha}\right)
\end{aligned} \tag{A.25}$$

We need:

$$\begin{aligned}
\frac{\partial^2 U^R[e,p,\alpha,\gamma]}{\partial p \partial \alpha} &= \tfrac{\partial q[e,\alpha]}{\partial \alpha}\left(b_L+\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)-\left(1-\gamma-q[e,\alpha]\right)\delta\tfrac{\partial U^R[e,p,\alpha,\gamma]}{\partial \alpha} \\
&\quad +\tfrac{\partial q[e,\alpha]}{\partial \alpha}p\delta\tfrac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}+\left(1-\left(1-\gamma-q[e,\alpha]\right)p\right)\delta\tfrac{\partial^2 U^R[e,p,\alpha,\gamma]}{\partial p\partial \alpha} \\
\text{(A.26)} \qquad &= \frac{\frac{\partial q[e,\alpha]}{\partial \alpha}\left(b_L+\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)-(1-\gamma-q[e,\alpha])\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \alpha}+\frac{\partial q[e,\alpha]}{\partial \alpha}p\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}}{1-(1-(1-\gamma-q[e,\alpha])p)\delta}
\end{aligned}$$

Substituting A.26 in A.25 gives:

$$\begin{aligned}
\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial p \partial \alpha} &= \tfrac{\partial^2 q[e,\alpha]}{\partial e\partial \alpha}\left(b_L+\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)+p\delta\tfrac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}\right)+\tfrac{\partial q[e,\alpha]}{\partial e} * \\
&\quad \left(\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \alpha}\right. \\
&\quad \left. +p\delta\frac{\frac{\partial q[e,\alpha]}{\partial \alpha}\left(b_L+\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)-(1-\gamma-q[e,\alpha])\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \alpha}+\frac{\partial q[e,\alpha]}{\partial \alpha}p\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}}{1-(1-(1-\gamma-q[e,\alpha])p)\delta}\right) \\
&= \left(\tfrac{\partial^2 q[e,\alpha]}{\partial e\partial \alpha}+\frac{\frac{\partial q[e,\alpha]}{\partial e}p\delta\frac{\partial q[e,\alpha]}{\partial \alpha}}{1-(1-(1-\gamma-q[e,\alpha])p)\delta}\right)\left(b_L+\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)+p\delta\tfrac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}\right) \\
&\quad +\tfrac{\partial q[e,\alpha]}{\partial e}\frac{1-\delta}{1-(1-(1-\gamma-q[e,\alpha])p)\delta}\delta\tfrac{\partial U^R[e,p,\alpha,\gamma]}{\partial \alpha} \\
&> 0
\end{aligned}$$

Because $b_L+\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)+p\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p} > 0$ (see A.7) and all other terms positive, $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial p\partial \alpha} > 0$. The next component is:

$$\begin{aligned}
\text{(A.27)} \quad \frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e \partial \alpha} &= \tfrac{\partial^3 q[e,\alpha]}{\partial e^2\partial \alpha}\left(b_H-(1-p)b_L+p\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right) \\
&\quad +\tfrac{\partial^2 q[e,\alpha]}{\partial e^2}p\delta\tfrac{\partial U^R[e,p,\alpha,\gamma]}{\partial \alpha}
\end{aligned}$$

As I have made no assumption about $\frac{\partial^3 q[e,\alpha]}{\partial e^2\partial \alpha}$, the sign of $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e\partial \alpha}$ is unknown. Moving on to the next element, and using $\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial e^*} = 0$ from the first order condition 2.4:

$$\begin{aligned}
\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial p \partial e} &= \tfrac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e\partial p} \\
\text{(A.28)} \qquad &= \tfrac{\partial^2 q[e,\alpha]}{\partial e^2}\left(b_L+\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)+p\delta\tfrac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}\right) < 0
\end{aligned}$$

Because $b_L + \delta\left(U^R[e,p,\alpha,\gamma] - U^O\right) + p\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p} > 0$ (see A.7), $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial p \partial e} < 0$. Finally (and again using $\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial e^*} = 0$ from the first order condition 2.4):

$$\begin{aligned}
\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e^2} &= \frac{\partial^3 q[e,\alpha]}{\partial e^3}\left(b_H - (1-p)\,b_L + p\delta\left(U^R[e,p,\alpha,\gamma] - U^O\right)\right) \\
&\quad + \frac{\partial^2 q[e,\alpha]}{\partial e^2} p\delta \frac{\partial U^R[e,p,\alpha,\gamma]}{\partial e} - \frac{\partial^3 c[e]}{\partial e^3} \\
&= \frac{\partial^3 q[e,\alpha]}{\partial e^3}\left(b_H - (1-p)\,b_L + p\delta\left(U^R[e,p,\alpha,\gamma] - U^O\right)\right) - \frac{\partial^3 c[e]}{\partial e^3} \qquad \text{(A.29)}
\end{aligned}$$

Because the signs of $\frac{\partial^3 q[e,\alpha]}{\partial e^3}$ and $\frac{\partial^3 c[e]}{\partial e^3}$ are not specified, we cannot determine the sign of $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e^2}$. In short, for the sign of $\frac{\partial^2 e^*}{\partial p \partial \alpha}$ we miss the signs of the following elements:

$$\frac{\partial^2 e^*}{\partial p \partial \alpha} = -\frac{\overset{+}{\frac{\partial^2 F^1}{\partial p \partial \alpha}} + \overset{+}{\frac{\partial e^*}{\partial p}}\overset{?}{\frac{\partial^2 F^1}{\partial e \partial \alpha}}}{\underset{-}{\frac{\partial F^1}{\partial e}}} - \frac{\overset{-}{\frac{\partial^2 F^1}{\partial p \partial e}} + \overset{+}{\frac{\partial e^*}{\partial p}}\overset{?}{\frac{\partial^2 F^1}{(\partial e)^2}}}{\underset{-}{\frac{\partial F^1}{\partial e}}}\overset{+}{\frac{\partial e^*}{\partial \alpha}}$$

If e^* is only implicitly defined, then we require assumptions about $\frac{\partial^3 q[e,\alpha]}{\partial e^2 \partial \alpha}$, $\frac{\partial^3 q[e,\alpha]}{\partial e^3}$, $\frac{\partial^3 c[e]}{\partial e^3}$, and the relative magnitude of $\frac{\partial^2 q[e,\alpha]}{\partial e^2}$, $\frac{\partial^3 c[e]}{\partial e^3}$, and $\frac{\partial q[e,\alpha]}{\partial e}$ in order to sign $\frac{\partial^2 e^*}{\partial p \partial \alpha}$. Thus, we lack the signs of the following elements for100

goal of determining $\frac{\partial p^*}{\partial \alpha}$:

$$\begin{aligned}
\frac{\partial F^2[p;\alpha,\gamma]}{\partial \alpha} &= \overset{?}{\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \alpha}} + \left(\overset{+}{\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \alpha}} + \overset{?}{\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}}\overset{+}{\frac{\partial e^*}{\partial \alpha}}\right)\overset{+}{\frac{\partial e^*}{\partial p}} \\
&\quad + \underset{+}{\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}}\underset{?}{\frac{\partial^2 e^*}{\partial p \partial \alpha}}
\end{aligned}$$

A.3.1.2. Easiness of task. For $\frac{\partial p^*}{\partial \gamma}$ we need to determine the sign of:

$$\begin{aligned}
\frac{\partial F^2[p;\alpha,\gamma]}{\partial \gamma} &= \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \gamma} + \left(\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \gamma} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\frac{\partial e^*}{\partial \gamma}\right)\frac{\partial e^*}{\partial p} \\
&\quad + \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\frac{\partial^2 e^*}{\partial p \partial \gamma}
\end{aligned}$$

Above we have established the following:

$$\begin{aligned}\frac{\partial e^*}{\partial \gamma} &> 0\\ \frac{\partial e^*}{\partial p} &> 0\\ \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} &> 0\end{aligned}$$

I explore the other components below.

$$\begin{aligned}\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \gamma} &= \delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)-(1-\gamma-q[e^*,\alpha])\,\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial \gamma}\\ &\quad +p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial p}+(1-(1-\gamma-q[e^*,\alpha])\,p)\,\delta\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p\partial\gamma}\\ &= \frac{\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)-(1-\gamma-q[e^*,\alpha])\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\gamma}+p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial p}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}\end{aligned} \tag{A.30}$$

Substituting A.18 and A.20 in A.30 gives:

$$\begin{aligned}\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \gamma} &= \frac{\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)-(1-\gamma-q[e^*,\alpha])\delta\frac{\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}\\ &\quad -\frac{p\delta\frac{(1-\gamma-q[e^*,\alpha])\delta\left(S^R[e^*,p,\alpha]-S^O\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}\\ &= \frac{(1-\delta-(1-\gamma-q[e^*,\alpha])p\delta)\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)-(1-\gamma-q[e^*,\alpha])\Delta Q}{\frac{1}{\delta}(1-\delta+(1-\gamma-q[e^*,\alpha])p\delta)^2}\end{aligned}$$

From this we can determine when this expression is negative:

$$\begin{aligned}\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p\partial\gamma} &< 0 \text{ i.f.f.}\\ (1-\delta-(1-\gamma-q[e^*,\alpha])\,p\delta)\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)-(1-\gamma-q[e^*,\alpha])\,\Delta Q &< 0\\ \left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]}-p\delta\right)\left(S^R[e^*,p,\alpha,\gamma]-S^O\right) &< \Delta Q\end{aligned}$$

Interestingly this condition is the same as for $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \alpha}$, see A.22. The next component is:

$$\begin{aligned}
\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \gamma} &= \frac{\partial q[e^*,\alpha]}{\partial e^*} p\delta \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial \gamma} + p\delta \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} \\
&\quad + (1-(1-\gamma-q[e^*,\alpha])\,p)\,\delta \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \gamma} \\
&= \frac{p\delta\left(\frac{\partial q[e^*,\alpha]}{\partial e^*}\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial \gamma} + \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta} \qquad \text{(A.31)} \\
&> 0
\end{aligned}$$

For the final component, $\frac{\partial^2 e^*}{\partial p \partial \gamma}$, we can make use of $\frac{\partial e^*}{\partial p} = -\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p} / \frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}$ (from A.3)

$$\begin{aligned}
\frac{\partial^2 e^*}{\partial p \partial \gamma} &= -\frac{\partial\left(\frac{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p}}{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}}\right)}{\partial \gamma} - \frac{\partial\left(\frac{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial p}}{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}}\right)}{\partial e}\frac{\partial e^*}{\partial \gamma} \\
&= -\frac{\frac{\partial F^1}{\partial e}\frac{\partial^2 F^1}{\partial p \partial \gamma} - \frac{\partial F^1}{\partial p}\frac{\partial^2 F^1}{\partial e \partial \gamma}}{\left(\frac{\partial F^1}{\partial e}\right)^2} - \frac{\frac{\partial F^1}{\partial e}\frac{\partial^2 F^1}{\partial p \partial e} - \frac{\partial F^1}{\partial p}\frac{\partial^2 F^1}{(\partial e)^2}}{\left(\frac{\partial F^1}{\partial e}\right)^2}\frac{\partial e^*}{\partial \gamma} \\
&= -\frac{\frac{\partial^2 F^1}{\partial p \partial \gamma} + \frac{\partial e^*}{\partial p}\frac{\partial^2 F^1}{\partial e \partial \gamma}}{\frac{\partial F^1}{\partial e}} - \frac{\frac{\partial^2 F^1}{\partial p \partial e} + \frac{\partial e^*}{\partial p}\frac{\partial^2 F^1}{(\partial e)^2}}{\frac{\partial F^1}{\partial e}}\frac{\partial e^*}{\partial \gamma}
\end{aligned}$$

Above we have established the following:

$$\begin{aligned}
\frac{\partial e^*}{\partial p} &> 0 \\
\frac{\partial e^*}{\partial \gamma} &> 0 \\
\frac{\partial F^1}{\partial e} &< 0
\end{aligned}$$

For the others:

$$\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial p \partial \gamma} = \frac{\partial q[e,\alpha]}{\partial e}\delta\left(\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \gamma} + p\frac{\partial^2 U^R[e,p,\alpha,\gamma]}{\partial p \partial \gamma}\right) \qquad \text{(A.32)}$$

We need:

$$\begin{aligned}\frac{\partial^2 U^R[e,p,\alpha,\gamma]}{\partial p \partial \gamma} &= b_L + \delta\left(U^R[e,p,\alpha] - U^O\right) - (1-\gamma-q[e,\alpha])\,\delta \frac{\partial U^R[e,p,\alpha]}{\partial \gamma} \\ &\quad + p\delta \frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p} + (1-(1-\gamma-q[e,\alpha])\,p)\,\delta \frac{\partial^2 U^R[e,p,\alpha,\gamma]}{\partial p \partial \gamma} \\ &= \frac{b_L + \delta\left(U^R[e,p,\alpha]-U^O\right) - (1-\gamma-q[e,\alpha])\delta \frac{\partial U^R[e,p,\alpha]}{\partial \gamma} + p\delta \frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}}{1-\delta+(1-\gamma-q[e,\alpha])p\delta} \end{aligned} \tag{A.33}$$

Substituting A.33 in A.32 gives:

$$\begin{aligned}\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial p \partial \gamma} &= \frac{\partial q[e,\alpha]}{\partial e}\delta \left(\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \gamma} + p \frac{b_L + \delta\left(U^R[e,p,\alpha]-U^O\right) - (1-\gamma-q[e,\alpha])\delta \frac{\partial U^R[e,p,\alpha]}{\partial \gamma} + p\delta \frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}}{1-\delta+(1-\gamma-q[e,\alpha])p\delta} \right) \\ &= \frac{\frac{\partial q[e,\alpha]}{\partial e}\delta\left((1-\delta)\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \gamma} + p\left(b_L + \delta\left(U^R[e,p,\alpha]-U^O\right) + p\delta\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p}\right)\right)}{1-\delta+(1-\gamma-q[e,\alpha])p\delta} > 0 \end{aligned} \tag{A.34}$$

Because $b_L + \delta\left(U^R[e,p,\alpha,\gamma] - U^O\right) + p\delta \frac{\partial U^R[e,p,\alpha,\gamma]}{\partial p} > 0$ (see A.7) and all other terms are positive, $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial p \partial \gamma} > 0$. The next component is:

$$\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e \partial \gamma} = \frac{\partial^2 q[e,\alpha]}{\partial e^2} p\delta \frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \gamma} \leq 0 \tag{A.35}$$

Because $\frac{\partial U^R[e,p,\alpha,\gamma]}{\partial \gamma} > 0$, $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e \partial \gamma} \leq 0$. In short, for the sign of $\frac{\partial^2 e^*}{\partial p \partial \gamma}$ we miss the sign of the following elements:

$$\frac{\partial^2 e^*}{\partial p \partial \gamma} = -\frac{\overset{+}{\frac{\partial^2 F^1}{\partial p \partial \gamma}} + \overset{+}{\frac{\partial e^*}{\partial p}}\,\overset{-}{\frac{\partial^2 F^1}{\partial e \partial \gamma}}}{\underset{-}{\frac{\partial F^1}{\partial e}}} - \frac{\overset{-}{\frac{\partial^2 F^1}{\partial p \partial e}} + \overset{+}{\frac{\partial e^*}{\partial p}}\,\overset{?}{\frac{\partial^2 F^1}{(\partial e)^2}}}{\underset{-}{\frac{\partial F^1}{\partial e}}}\,\overset{+}{\frac{\partial e^*}{\partial \gamma}}$$

If e^* is only implicitly defined, then we require assumptions about $\frac{\partial^3 q[e,\alpha]}{\partial e^3}$ and $\frac{\partial^3 c[e]}{\partial e^3}$ in order to sign $\frac{\partial^2 e^*}{\partial p \partial \gamma}$. Thus, we lack the signs of the following elements to of determine $\frac{\partial p^*}{\partial \gamma}$:

$$\begin{aligned}\frac{\partial F^2[p;\alpha,\gamma]}{\partial \gamma} &= \overset{?}{\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \gamma}} + \left(\overset{+}{\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \gamma}} + \overset{?}{\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}}\,\overset{+}{\frac{\partial e^*}{\partial \gamma}} \right) \overset{+}{\frac{\partial e^*}{\partial p}} \\ &\quad + \underset{+}{\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}}\,\underset{?}{\frac{\partial^2 e^*}{\partial p \partial \gamma}} \end{aligned}$$

A.3.2. Specific functional forms

I this section I assume $\frac{\partial^2 q[e,\alpha]}{\partial e} = 0$ and $\frac{\partial^3 c[e]}{\partial e^3} = 0$.

A.3.2.1. Controllability of task (proposition 4). To determine $\frac{\partial p^*}{\partial \alpha}$ we need to establish the signs of three components: $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \alpha}$, $\left(\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \alpha} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\frac{\partial e^*}{\partial \alpha}\right)$, and $\frac{\partial^2 e^*}{\partial p \partial \alpha}$. Given the specific functional form, the first component remains indeterminate and I show below that the second and third are positive. First, if and only if the following condition holds $\left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]} - p\delta\right)\left(S^R[e^*,p,\alpha,\gamma] - S^O\right) < \Delta Q$, $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \alpha}$ is negative (see A.21). Second, while it is still not possible to determine the sign of $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}$, it is possible to establish that $\left(\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \alpha} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\frac{\partial e^*}{\partial \alpha}\right)$ is always positive. We make use of $\frac{\partial e^*}{\partial \alpha} = -\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \alpha} / \frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}$ (see A.4):

$$\begin{aligned}
\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \alpha} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\frac{\partial e^*}{\partial \alpha} &> 0 \text{ i.f.f.} \\
\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2} &> -\frac{\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \alpha}}{\frac{\partial e^*}{\partial \alpha}} \\
\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2} &> \frac{\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \alpha}\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}}{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial \alpha}}
\end{aligned}$$

If we substitute the different elements from 2.5, A.11, A.23, and A.24 and take into account the specific assumption about the functional forms, we get:

$$\frac{2\frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} - \frac{\partial^2 c[e^*]}{\partial (e^*)^2}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}$$

$$> \frac{\frac{\frac{\partial^2 q[e^*,\alpha]}{\partial e^* \partial \alpha}\left(\Delta Q + p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right) + \frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial \alpha} + \frac{\partial q[e^*,\alpha]}{\partial \alpha}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}\left(-\frac{\partial^2 c[e]}{\partial e^2}\right)}{\left(\frac{\partial^2 q[e,\alpha]}{\partial e \partial \alpha} + \frac{\frac{\partial q[e,\alpha]}{\partial e}p\delta\frac{\partial q[e,\alpha]}{\partial \alpha}}{1-\delta+(1-\gamma-q[e,\alpha])p\delta}\right)\left(b_H - (1-p)\,b_L + p\delta\left(U^R[e,p,\alpha,\gamma] - U^O\right)\right)}$$

$$2\frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}$$

$$> \frac{\partial^2 c[e]}{\partial e^2}\left(1 - \frac{\frac{\partial^2 q[e^*,\alpha]}{\partial e^* \partial \alpha}\left(\Delta Q + p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right) + \frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial \alpha} + \frac{\partial q[e^*,\alpha]}{\partial \alpha}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}}{\left(\frac{\partial^2 q[e,\alpha]}{\partial e \partial \alpha} + \frac{\frac{\partial q[e,\alpha]}{\partial e}p\delta\frac{\partial q[e,\alpha]}{\partial \alpha}}{1-\delta+(1-\gamma-q[e,\alpha])p\delta}\right)\left(b_H-(1-p)b_L+p\delta(U^R[e,p,\alpha,\gamma]-U^O)\right)}\right)$$

Because the left hand side is positive, this inequality must hold if the right hand side is negative. This is the case if:

$$\frac{\partial^2 q[e^*,\alpha]}{\partial e^*\partial\alpha}\left(\Delta Q + p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right)+\frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\alpha}+\frac{\partial q[e^*,\alpha]}{\partial \alpha}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}$$
$$> \left(\frac{\partial^2 q[e,\alpha]}{\partial e\partial\alpha}+\frac{\frac{\partial q[e,\alpha]}{\partial e}p\delta\frac{\partial q[e,\alpha]}{\partial\alpha}}{1-\delta+(1-\gamma-q[e,\alpha])p\delta}\right)\left(b_H-(1-p)\,b_L+p\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)\right)$$

Because $\Delta Q + p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right) > b_H-(1-p)\,b_L+p\delta\left(U^R[e,p,\alpha,\gamma]-U^O\right)$, $\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\alpha} = \frac{\frac{\partial q[e^*,\alpha]}{\partial\alpha}\left(\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}$, and $\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} > 0$, this inequality always holds. Hence, $\left(\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial\alpha}+\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\frac{\partial e^*}{\partial\alpha}\right)$ is always positive. Given the specific functional forms, $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e\partial\alpha} = 0$ (see A.27), $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial p\partial e} = 0$ (see A.28), $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e^2} = 0$ (see A.29), and $\frac{\partial^2 e^*}{\partial p\partial\alpha}$ simplifies to an expression that is always positive:

$$\frac{\partial^2 e^*}{\partial p\partial\alpha} = -\frac{\overset{+}{\frac{\partial^2F^1}{\partial p\partial\alpha}} + \overset{+}{\frac{\partial e^*}{\partial p}}\overset{0}{\frac{\partial^2F^1}{\partial e\partial\alpha}}}{\underset{-}{\frac{\partial F^1}{\partial e}}} - \frac{\overset{0}{\frac{\partial^2F^1}{\partial p\partial e}}+\overset{+}{\frac{\partial e^*}{\partial p}}\overset{0}{\frac{\partial^2F^1}{(\partial e)^2}}}{\underset{-}{\frac{\partial F^1}{\partial e}}}\overset{+}{\frac{\partial e^*}{\partial\alpha}} = -\frac{\overset{+}{\frac{\partial^2F^1}{\partial p\partial\alpha}}}{\underset{-}{\frac{\partial F^1}{\partial e}}} > 0$$

The sign of $\frac{\partial p^*}{\partial\alpha}$ is the same as $\frac{\partial F^2[p;\alpha,\gamma]}{\partial\alpha}$, whose elements are all always positive except for $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p\partial\alpha}$:

$$\frac{\partial F^2[p;\alpha,\gamma]}{\partial\alpha} = \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p\partial\alpha}+\left(\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial\alpha}+\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\frac{\partial e^*}{\partial\alpha}\right)\frac{\partial e^*}{\partial p}$$
$$+\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\frac{\partial^2 e^*}{\partial p\partial\alpha}$$

$\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p\partial\alpha}$ is negative if and only if $\left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]}-p\delta\right)\left(S^R[e^*,p,\alpha,\gamma]-S^O\right) > \Delta Q$. Hence, proposition 4: The condition $\left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]}-p\delta\right)\left(S^R[e^*,p,\alpha,\gamma]-S^O\right) > \Delta Q$ is necessary but not sufficient for the optimal threat level to be decreasing in the controllability of the task ($\frac{\partial p^*}{\partial\alpha} < 0$).

A.3.2.2. Easiness of task (proposition 5). To determine $\frac{\partial p^*}{\partial\gamma}$ we need to establish the signs of three components: $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p\partial\gamma}$, $\left(\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial\gamma}+\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\frac{\partial e^*}{\partial\gamma}\right)$, and $\frac{\partial^2 e^*}{\partial p\partial\gamma}$. Given the specific functional form, the first component remains indeterminate, while the second and third are positive. First, if and only if the following condition holds $\left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]}-p\delta\right)\left(S^R[e^*,p,\alpha,\gamma]-S^O\right) < \Delta Q$, $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p\partial\gamma}$ is negative (see

A.30). Second, while it is still not possible to determine the sign of $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial(e^*)^2}$, it is possible to establish that $\left(\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial\alpha} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial(e^*)^2}\frac{\partial e^*}{\partial\gamma}\right)$ is always positive. We make use of $\frac{\partial e^*}{\partial\gamma} = -\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial\gamma}/\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}$ (see A.5):

$$\begin{aligned}
\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial\gamma} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial(e^*)^2}\frac{\partial e^*}{\partial\gamma} &> 0 \text{ i.f.f.}\\
\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial(e^*)^2} &> -\frac{\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial\gamma}}{\frac{\partial e^*}{\partial\gamma}}\\
\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial(e^*)^2} &> \frac{\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial\gamma}\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial e}}{\frac{\partial F^1[e;p,\alpha,\gamma]}{\partial\gamma}}
\end{aligned}$$

If we substitute the different elements from 2.5, A.14, A.24, and A.31 and take into account the specific assumption about the functional forms, we get:

$$\begin{aligned}
\frac{2\frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} - \frac{\partial^2 c[e^*]}{\partial(e^*)^2}}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta} &> \frac{\frac{p\delta\left(\frac{\partial q[e^*,\alpha]}{\partial e^*}\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\gamma} + \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}\left(-\frac{\partial^2 c[e]}{\partial e^2}\right)}{\frac{\partial q[e,\alpha]}{\partial e}p\delta\frac{b_H-(1-p)b_L+p\delta\left(U^R[e,p,\alpha]-U^O\right)}{1-(1-(1-\gamma-q[e,\alpha])p)\delta}}\\
2\frac{\partial q[e^*,\alpha]}{\partial e^*}p\delta\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} &> \frac{\partial^2 c[e^*]}{\partial(e^*)^2}\left(1 - \frac{\frac{\partial q[e^*,\alpha]}{\partial e^*}\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\gamma} + \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}}{\frac{\partial q[e,\alpha]}{\partial e}\frac{b_H-(1-p)b_L+p\delta\left(U^R[e,p,\alpha]-U^O\right)}{1-(1-(1-\gamma-q[e,\alpha])p)\delta}}\right)
\end{aligned}$$

Because the left hand side is positive, this inequality must hold if the right hand side is negative. This is the case if:

$$\begin{aligned}
&\frac{\partial q[e^*,\alpha]}{\partial e^*}\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\gamma} + \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\\
&> \frac{\partial q[e,\alpha]}{\partial e}\frac{b_H-(1-p)b_L+p\delta\left(U^R[e,p,\alpha]-U^O\right)}{1-(1-(1-\gamma-q[e,\alpha])p)\delta}
\end{aligned}$$

Because $\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial\gamma} = \frac{\Delta Q+p\delta\left(S^R[e^*,p,\alpha,\gamma]-S^O\right)}{1-\delta+(1-\gamma-q[e^*,\alpha])p\delta}$, $\Delta Q + p\delta\left(S^R[e^*,p,\alpha,\gamma] - S^O\right) > b_H - (1-p)\,b_L + p\delta\left(U^R[e,p,\alpha,\gamma] - U^O\right)$, and $\frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*} > 0$, this inequality always holds. Hence, $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^*\partial\alpha} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial(e^*)^2}\frac{\partial e^*}{\partial\gamma}$ is always positive. Given the specific functional forms, $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e\partial\gamma} = 0$ (see A.35), $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial p\partial e} = 0$ (see A.28), $\frac{\partial^2 F^1[e;p,\alpha,\gamma]}{\partial e^2} = 0$ (see A.29), and $\frac{\partial^2 e^*}{\partial p\partial\gamma}$ simplifies to an expression that is always positive:

$$\frac{\partial^2 e^*}{\partial p\partial\gamma} = -\frac{\overset{+}{\frac{\partial^2 F^1}{\partial p\partial\gamma}} + \overset{+}{\frac{\partial e^*}{\partial p}}\overset{0}{\frac{\partial^2 F^1}{\partial e\partial\gamma}}}{\underset{-}{\frac{\partial F^1}{\partial e}}} - \frac{\overset{0}{\frac{\partial^2 F^1}{\partial p\partial e}} + \overset{+}{\frac{\partial e^*}{\partial p}}\overset{0}{\frac{\partial^2 F^1}{(\partial e)^2}}}{\underset{-}{\frac{\partial F^1}{\partial e}}}\overset{+}{\frac{\partial e^*}{\partial\gamma}} = -\frac{\overset{+}{\frac{\partial^2 F^1}{\partial p\partial\gamma}}}{\underset{-}{\frac{\partial F^1}{\partial e}}} > 0$$

The sign of $\frac{\partial p^*}{\partial \gamma}$ is the same as $\frac{\partial F^2[p;\alpha,\gamma]}{\partial \gamma}$, whose elements are all always positive except for $\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \gamma}$:

$$\begin{aligned}\frac{\partial F^2[p;\alpha,\gamma]}{\partial \gamma} &= \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \gamma} + \left(\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial e^* \partial \gamma} + \frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial (e^*)^2}\frac{\partial e^*}{\partial \gamma}\right)\frac{\partial e^*}{\partial p} \\ &\quad + \frac{\partial S^R[e^*,p,\alpha,\gamma]}{\partial e^*}\frac{\partial^2 e^*}{\partial p \partial \gamma}\end{aligned}$$

$\frac{\partial^2 S^R[e^*,p,\alpha,\gamma]}{\partial p \partial \gamma}$ is negative if and only if $\left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]} - p\delta\right)\left(S^R[e^*,p,\alpha,\gamma] - S^O\right) > \Delta Q$. Hence, proposition 5: The condition $\left(\frac{1-\delta}{1-\gamma-q[e^*,\alpha]} - p\delta\right)\left(S^R[e^*,p,\alpha,\gamma] - S^O\right) > \Delta Q$ is necessary but not sufficient for the optimal threat level to be decreasing in the easiness of the task ($\frac{\partial p^*}{\partial \gamma} < 0$).

APPENDIX B

Heckman correction

In chapter 3 we are interested in the treatment effect of vertical integration on trust. In our context the treatment effect of vertical integration is the difference in trust (T) for an internal transaction and trust for the same transaction if it were organized externally:

$$T(\text{internal}) - T(\text{external})$$

For a given transaction we cannot measure T(internal) and T(external) at the same time. The role of empirical research is to measure the factual and come up with reasonable approximations for the counterfactual. We use a structural model with a trust and a selection equation. Trust for transaction j is a function of vertical integration (V_j), transaction characteristics (X_j), and a mean zero error term (ε_j):

$$T_j = \alpha V_j + X_j\beta + \varepsilon_j \tag{B.1}$$

Vertical integration is a dummy variable that is one if the transaction is organized internally and zero otherwise. The average treatment effect is:

$$E[T_j(\text{internal}) - T_j(\text{external})] = \alpha$$

The average treatment effect answers the question *for a randomly drawn transaction from the population of all transactions what is the average difference in internal and external trust?*

We define a selection equation for vertical integration. The decision to vertically integrate (V_j) is the outcome of an unobserved continuous variable (V_j^*):

$$
\begin{aligned}
V_j^* &= X_j\gamma + Z_j\delta + u_j \\
V_j &= 1 \text{ if } V_j^* > 0, \text{ and } V_j = 0 \text{ otherwise}
\end{aligned}
\tag{B.2}
$$

where u_j is a mean zero error term. Z_j captures transaction characteristics that influence the vertical integration decision but not the level of trust. It is included for identification. We will come back to this later.

Consider the expected value of trust given transaction characteristics and the vertical integration decision:

$$
\begin{aligned}
E[T_j|X_j, V_j] &= E[\alpha V_j + X_j\beta + \varepsilon_j|X_j, V_j] \\
&= \alpha V_j + X_j\beta + E[\varepsilon_j|X_j, V_j]
\end{aligned}
\tag{B.3}
$$

If the conditional expectation of the error term is not zero, then one of the key assumptions underlying the OLS framework is violated. Estimating the trust equation B.1 directly from a sample would lead to a biased estimate of the treatment effect (α). If we assume that X_j is exogenous, then the conditional expectation is not zero if vertical integration is not a random decision and we cannot include all factors that jointly affect trust and the vertical integration decision. The resulting bias is referred to as endogeneity bias, because vertical integration is endogenous to the model. Through directly modeling the selection equation, we can correct for the endogeneity bias.

If vertical integration is endogenous in the trust equation B.1, then the errors ε_j of the trust equation and u_j of the selection equation B.2 are correlated. We assume that ε_j are u_j bivariate normal with

$$
Cov(\varepsilon_j, u_j) = \begin{pmatrix} \sigma & \rho \\ \rho & 1 \end{pmatrix}
$$

We use the general result (see for example Maddala (1983, p. 367)):

$$E[y|z > -c] = \sigma_{y,z}\sigma_y \frac{\phi(c)}{\Phi(c)}$$
$$E[y|z < -c] = \sigma_{y,z}\sigma_y \frac{-\phi(c)}{1-\Phi(c)}$$

where y and z have a bivariate normal distribution with $y(0,\sigma_y)$, $z(0,1)$, and correlation $\sigma_{y,z}$. Expected trust conditional on the vertical integration decision is:

$$\begin{aligned} E[T_j|X_j, V_j = 1] &= \alpha V_j + X_j\beta + E[\varepsilon_j|X_j, V_j^* > 0] \\ &= \alpha V_j + X_j\beta + E[\varepsilon_j|X_j, u_j > -X_j\gamma - Z_j\delta] \\ &= \alpha V_j + X_j\beta + \rho\sigma\frac{\phi(X_j\gamma + Z_j\delta)}{\Phi(X_j\gamma + Z_j\delta)} \quad \text{(B.4)} \\ E[T_j|X_j, V_j = 0] &= \alpha V_j + X_j\beta + E[\varepsilon_j|X_j, V_j^* \leq 0] \\ &= \alpha V_j + X_j\beta + E[\varepsilon_j|X_j, u_j \leq -X_j\gamma - Z_j\delta] \\ &= \alpha V_j + X_j\beta + \rho\sigma\frac{-\phi(X_j\gamma + Z_j\delta)}{1-\Phi(X_j\gamma + Z_j\delta)} \quad \text{(B.5)} \end{aligned}$$

We take the following steps to estimate the model. First, we estimate γ and δ using a probit model for the vertical integration decision B.2. Second, we use these coefficients to calculate for each internal transaction $\phi(X_j\gamma + Z_j\delta)/\Phi(X_j\gamma + Z_j\delta)$ and for each external transaction $-\phi(X_j\gamma + Z_j\delta)/1-\Phi(X_j\gamma + Z_j\delta)$. These ratios are called the non-selection hazard. Third, using the non-selection hazard (λ) we estimate an OLS model:

$$T_j = \widehat{\alpha}V_j + X_j\widehat{\beta} + \lambda(X_j\gamma + Z_j\delta)\widehat{\theta} + e_j \quad \text{(B.6)}$$

where e_j is a mean zero error. The resulting coefficient $\widehat{\alpha}$ is a consistent estimate for the average treatment effect. Note that for identification Z_j features in B.6 only through the non-selection hazard. In the absence of Z_j, the system of equations is identified only on the basis of the distributional assumptions of u_j. Furthermore in the absence of Z_j, the non-selection hazard is strongly correlated with X_j. This can result in very imprecise estimates (Wooldridge, 2002).

The non-selection hazard is an estimate for the average conditional error term $E[\varepsilon_j|X_j, V_j]$ in B.3. The non-selection hazard is always positive, because the density and cumulative distribution functions are between zero and one. The sign of the non-selection hazard coefficient $(\widehat{\theta})$ can however be negative, zero, or positive. If $\widehat{\theta}$ is zero, then $E[\varepsilon_j|X_j, V_j] = 0$ and vertical integration is not endogenous. Directly estimating the trust equation B.1 without the non-selection hazard gives an unbiased estimate of the treatment effect (α). If $\widehat{\theta} > 0$, then $E[\varepsilon_j|X_j, V_j] > 0$ implying that $E[\varepsilon_j|X_j, V_j = 1] > 0$ and $E[\varepsilon_j|X_j, V_j = 0] > 0$. $E[\varepsilon_j|X_j, V_j = 1] > 0$ implies that a randomly selected internal transaction from the population of all internal transactions with characteristics X_j is expected to have higher trust than if a randomly selected transaction from the population of all transactions with characteristics X_j were to be organized internally. Similarly, $E[\varepsilon_j|X_j, V_j = 0] > 0$ implies that a randomly selected external transaction from the population of all external transactions with characteristics X_j is expected to have higher trust than if a randomly selected transaction from the population of all transactions with characteristics X_j were to be organized externally. For $\widehat{\theta} < 0$, the opposite holds.

Because we obtain a direct estimate of the average conditional error term $E[\varepsilon_j|X_j, V_j]$ in B.3, we can also use the procedure above to estimate a model which has one (or more) interaction effect(s) with vertical integration. For example, assume that the treatment effect depends on the level of X_j:

$$T_j = \alpha V_j + \gamma X_j V_j + X_j \beta + \varepsilon_j$$

The expected value of trust given transaction characteristics and the vertical integration decision becomes:

$$\begin{aligned} E[T_j|X_j, X_jV_j, V_j] &= E[\alpha V_j + \gamma X_jV_j + X_j\beta + \varepsilon_j|X_j, X_jV_j, V_j] \\ &= \alpha V_j + \gamma X_jV_j + X_j\beta + E[\varepsilon_j|X_j, X_jV_j, V_j] \end{aligned}$$

Because X_j and V_j fully determine X_jV_j, an expectation conditional on X_j, X_jV_j, V_j is equivalent to an expectation conditional on X_j, V_j. Hence, the expected conditional error term $E[\varepsilon_j|X_j, X_jV_j, V_j]$ is equal to $E[\varepsilon_j|X_j, V_j]$. In the exact same way as B.4 and B.5, we can obtain an expression for $E[\varepsilon_j|X_j, V_j]$ that we can empirically estimate:

$$\begin{aligned} E[\varepsilon_j|X_j, X_jV_j, V_j = 1] &= E[\varepsilon_j|X_j, V_j = 1] \\ &= E[\varepsilon_j|X_j, V_j^* > 0] \\ &= \rho\sigma\frac{\phi(X_j\gamma + Z_j\delta)}{\Phi(X_j\gamma + Z_j\delta)} \\ E[\varepsilon_j|X_j, X_jV_j, V_j = 0] &= E[\varepsilon_j|X_j, V_j = 0] \\ &= E[\varepsilon_j|X_j, V_j^* \leq 0] \\ &= \rho\sigma\frac{-\phi(X_j\gamma + Z_j\delta)}{1 - \Phi(X_j\gamma + Z_j\delta)} \end{aligned}$$

We get an estimate of the expected conditional error term from the non-selection hazard. Furthermore the inclusion of the non-selection hazard when estimating the trust equation leads to consistent estimates of all coefficients (on the maintained assumption that all X_j are exogenous), because we account for any correlation between V_j and the error term. Hence, the Heckman correction is also appropriate for interaction effects with vertical integration.