KU LEUVEN

CENTER FOR ECONOMIC STUDIES

DISCUSSION PAPER SERIES
DPS17.11

AUGUST 2017

Governing supply relationships: evidence from the automotive industry

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Econometrics

Faculty of Economics
and Business

Governing supply relationships: Evidence from the automotive industry[1]

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August 2017

Abstract

A large empirical literature analyzes determinants of the make-or-buy decision. Transaction cost economics highlights the role of asset specificity, the property rights theory focuses on the relative marginal contributions to joint surplus creation, and some evidence suggests that making transactions more contractible facilitates outsourcing. We use a unique transaction-level dataset of outsourced automotive components to predict carmakers' choices between four distinct ways of organizing sourcing relationships. We derive conditional predictions for three characteristics: (i) the complexity or contractibility of a transaction, (ii) how objectively codifiable performance is, and (iii) the supplier's capabilities. For example, while dominant buyer investments might predict vertical integration, as in the property rights theory, other characteristics might convince a buyer to simply re-organize the collaboration with the supplier in a more suitable way. Our results suggest that "buy" relationships differ systematically and that the predictive power of our variables extend from the make-or-buy decision to how-to-buy.

[1] We would like to thank participants in seminars at Bielefeld, KU Leuven, LSE, the NBER, and Utrecht, in particular Tim Sturgeon, Steve Tadelis and Frank Verboven, for their comments. Financial support from FWO and KU Leuven Program Financing "Governments and Markets" is gratefully acknowledged. Contact information: Johannes Van Biesebroeck, Department of Economics, KU Leuven, Naamsestraat 69, 3000 Leuven, Belgium. Email: Jo.VanBiesebroeck@kuleuven.be.

1. Introduction

Most studies of the make-or-buy decision motivate their estimating equation by appealing to a specific theory that predicts a positive or negative effect of a key explanatory factor on the probability of outsourcing. One of the best known examples is Monteverde and Teece (1982), who find that car manufacturers are more likely to produce components in-house, rather than buy externally, if their design requires more engineering effort. This approach has two related problems. First, alternative theories that highlight different explanatory factors can provide contradictory predictions. Second, lumping all forms of outsourcing into a single "buy" category ignores a lot of interesting variation in the collaboration between buyers and suppliers, which can differ by contract or organizational design.

Monteverde and Teece (1982) work in the transaction cost economics (TCE) framework and emphasize that high engineering effort will involve transaction-specific assets and bring uncertainty. It thus increases the chance of holdup as the carmaker and supplier, bound together by their assets, risk arguing over the division of unforeseen costs when a design needs to be adjusted. However, other theories highlight other dimensions of a transaction that might dominate decision making. For example, the property rights theory (PRT) of Grossman and Hart (1986) argues that outsourcing, i.e. letting an external supplier rather than an in-house division produce the component, moves control over sunk investments from the buyer to the supplier. The decision to "buy" a component strengthens the bargaining power, and thus the investment incentives, of the entity producing the input. Depending on the relative importance of this investment, it can sway the make-or-buy decision one way or the other. But what should a firm do if engineering effort is high, but has to be provided by the supplier (or internal sub-division)? What if predictions of the two theories conflict?

One way to make progress is to take a closer look at the different ways buyers and suppliers organize their relationships and distinguish between various types of outsourcing. In our empirical analysis we work with a dataset that contains approximately 55,000 sourcing transactions in the automotive industry, information that is usually confidential and rarely observed. Each transaction is identified by the following triplet: (i) a car model (buyer), (ii) a supplying firm, and (iii) an automotive component. Cars are very complex products consisting of a bewildering number of components which makes the automotive industry one of the most downstream manufacturing industries (Antràs, Chor, Fally and Hillberry, 2012). Carmakers need to interact with virtually all other manufacturing industries, sourcing different types of components in a wide range of circumstances. We investigate whether firms tailor their supplier governance, i.e. the way they collaborate with suppliers, to the situation.

Table 1 lists a few patterns for three of the suppliers in our dataset: the average fraction of sales going to each supplier's most important buyer, the supplier's (global) market share in its principal product, and the share of a product's (global) market share accounted for by an average client.[2] The large differences between suppliers suggest that it is unlikely to be a good idea to lump all types of outsourcing together, as is done in the make-or-buy literature. Some studies have explicitly considered more complex forms of firm-to-firm relationships, called *networks* of suppliers by Powell (1990) or *hybrid* modes of organization by Ménard (2013).

Table 1: Examples of buyer-supplier interactions

Supplier name	Most important component	% of sales going to most important buyer	% of product's global market share by this supplier	% of product's global market share by average client
Smarteq	infotainment	97%	1%	19%
Gallino Plasturgia	bumper	15%	1%	3%
Wescast	exhaust manifolds	34%	39%	8%

Note: Own calculations based on full dataset.

To go beyond the make-or-buy dichotomy and investigate firms' choices between several organizational forms, we face two challenges. First, we need to define and identify a discrete set of supplier governance types. The legal definition of firm ownership directly distinguishes in-house production from arm's length outsourcing. To distinguish objectively between forms of governance one needs a mapping from the observable features of buyer-supplier interactions to a set of governance types. Such a mapping should be applicable in a variety of economic settings. Second, to be useful in empirical work, we need to predict firms' choices between governance types using observed characteristics of the transactions, or of the buyers and suppliers.

[2] All market shares are calculated over the transactions we observe; in the Data section below we discuss the sample and variable construction in detail.

Rather than exhaustively partitioning all observed relationships into a few types, we associate each governance type that we consider with a continuous proxy variable. For example, in a so-called *captive relationship* the buyer provides the supplier with technological support and guarantees it a stream of sales, but demands exclusivity in return.[3] The number of clients a supplier works for will vary inversely with the probability that the relationship is of a captive type. These proxy variables are the dependent variables of our regressions and replace the vertical integration dummy in the make-or-buy literature.[4] For each of the four governance types that we consider, we estimate a separate equation. Case studies of different industries played an important role in identifying the possible forms of buyer-supplier collaboration and the associated proxy variables. Additional governance types can be added if one is able to propose a defining feature that sets such relationships apart from other forms.

We further argue that the same explanatory variables that are able to predict make-or-buy decisions, and have been studied previously, also influence firms' choices between these supplier governance types. We consider three characteristics of component or firms, each motivated by a distinct (economic) theory of the firm: ability to write complete contracts, degree of asset specificity, and the relative importance of marginal investments (of suppliers). We will illustrate that these characteristics are closely related to the three determinants of governance used in the widely cited study of Gereffi, Humphrey and Sturgeon (2008) in the literature on global value chains: complexity, codifiability, and supplier capabilities.

Our contribution then is twofold. First, without developing an original theory for each trade-off between two governance types, as in Bajari and Tadelis (2001) for two types of contracting, nor micro-founding a unifying theory that explicitly nests several explanations, as in Gibbons (2005), we propose a unified framework and focus on conditional predictions of the impact of each characteristic on the type of governance, holding other characteristics constant. Other studies are often able to focus on the effect of one particular explanatory factor because their sample comes from a setting that implicitly holds many other factors

[3] Captive supply relationships have a long history in the automotive industry. Klein (2007) investigates the failed attempt of General Motors to hold Fisher Body a captive supplier.

[4] If our sample also included buyer-component pairs that are sourced in-house, we could add the integration dummy as a fifth proxy variable and add in-house production as an addition governance type in the analysis. Schmitt and Van Biesebroeck (2017) propose a way to expand the sample and study the make-or-buy decision with the same dataset.

constant. For example, in the context of the make-or-buy decision, a high relative importance of supplier investments only predicts outsourcing if contracts are incomplete. Otherwise, a buyer could contractually specify performance requirements, irrespective of the organizational form. Similarly, specific investments only predict integration if a buyer cannot contractually specify a supplier's compensation for future adjustments and if the supplier's investment is not so dominant to make in-house production entirely inefficient. Because the carmakers in our sample source components from a wide range of industries and circumstances, we need to explicitly control for explanatory factors linked to different theories. The marginal impact of each characteristic is only unambiguous if other characteristics are held constant.

Second, we estimate the impact of the proposed variables on the choice of governance using a unique transaction-level dataset of sourcing relationships in the automotive industry. In contrast with the existing literature which predicts which activities should be organized in-house or outsourced, we predict what type of supply relationship a buyer should establish, i.e. we estimate the how-to-buy choice rather than the make-or-buy choice. Using the patterns in the supply relationships that we observe in the overall dataset, we distinguish between four forms of supplier governance (the dependent variables) and we relate them to three explanatory variables that are motivated by established theories of the firm: complexity or contractibility (contract theory), codifiability or asset-specificity (TCE), and supplier capabilities or relative importance of marginal investments (PRT).

The estimation results support the theoretical predictions. Less complex components are more likely to be sourced through arm's length *market* type of governance. Components for which it is difficult to objectively codify performance requirements are more likely to be sourced through a *relational* type of governance where suppliers produce only a few components, but collaborate closely with a few buyers. Suppliers with low capabilities are more likely to work in a *captive* relationship, where they are beholden to a large buyer. Supplier governance types have an ambiguous relationship with many characteristics because they share the sign of a marginal effect with at least one other type. We obtain many more unambiguous sign predictions if we make pairwise comparisons between two types, and the estimated effect are in line with predictions in almost all cases. A key takeaway from the analysis is thus that it is possible to distinguish different "buy" relationships and that the predictive power of our variables extend from the make-or-buy decision to how-to-buy.

Another takeaway is that even complex components are only produced in-house if both codifiability (the TCE variable) and supplier capability (the PRT variable) are low. If only one of these dimensions is problematic, outsourcing is still feasible, but the collaboration with suppliers will take a particular form.

Our findings relate to those three literatures that show transactions to be more easily outsourceable if they possess a certain feature. The results for complexity complement Maskin and Tirole (1999) who show that the ability to redefine transactions such that they are describable by contracts facilitates outsourcing. It also relates to Bajari and Tadelis (2001) who show that the contract choice, fixed-price or cost-plus, depends on the feasibility of providing the supplier with a comprehensive design. The results for codifiability complement Monteverde and Teece (1982) and Levin and Tadelis (2010) who show that high transaction costs of contracting makes it harder for cities to privatize a service. And our results on supplier capabilities complement the insurance example in Grossman and Hart (1986) or Woodruff (2002) who finds that segments with high fashion turnover see greater prominence of independent stores that need to expend effort learning about this season's demand.[5]

We build on the literature, mostly in management and geography, that studies the range of sourcing arrangements between the extremes of make-or-buy. Powell (1990) and Ménard (2013) highlight the varied forms of firm interaction one can observe and how various theories simultaneously influence firms' decisions. Bensaou (1999) and Gereffi, Humphrey, and Sturgeon (2005) propose a particular typology of organization modes. Our analysis is particularly close to the last approach which has been used as a framework to study the organization of industries in a myriad of settings. We illustrate how the three characteristics that they consider as determinants of governance modes can be directly related to prominent theories in economics. Our empirical work can be considered a cross-industry (or cross-product) confirmation of the case study evidence that has accumulated in that literature.[6]

The remainder of the paper is organized as follows. In Section 2 we outline the theoretical framework that guides the analysis. In Section 3 we present the data and in Section 4 the

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[5] Lafontaine and Slade (2009) provide a broad overview of the empirical literature.

[6] The website www.globalvaluechains.org lists 1,063 sources (as of July 18, 2017), including 445 journal articles, 52 books, and 133 book chapters, that study the organization of global value chains. Most of them (966) are case studies that are classified by industry. Clothing/apparel and food industries are researched most intensely, but 42 industries are covered by at least 5 studies.

empirical model. Section 5 contains a discussion of the estimation results and implications and conclusions are presented in Section 6.

2. Framework

2.1 Conditional predictions

When empirical papers establish a link between an explanatory variable of interest and firms' choices to outsource an input or not, it should be interpreted as a conditional prediction, as illustrated in Table 2. For example, we only expect a positive relationship between engineering intensity and the make-or-buy decision in Monteverde and Teece (1982) if other conditions are satisfied as well. In particular, the contribution of supplier investments to this engineering effort should not be so large, to make in-house production entirely inefficient due to the diminished investment incentives for the supplier. If supplier investments were all that mattered in the creation of surplus, it would be prohibitively costly not to make the supplier a residual claimant and the make-option would never be chosen. Moreover, the engineering efforts should not be verifiable or the requirements of satisfactory performance too complex to specify contractually. Otherwise, a well-designed contract could obviate the need for changing the organizational form.

Joskow (1985)'s study of the impact of transaction costs on contracting arrangements between electricity generators and coal suppliers explicitly mentions similar assumptions that are often implicit. Focusing on various dimensions of asset specificity, he finds that most generators rely on contractual restrictions and pricing arrangements to split the surplus and provide adequate performance incentives. Only in the most extreme circumstances, as in the case of mine-mouth generation plants, does asset specificity lead to vertical integration. Even here, it requires low uncertainty regarding mine productivity, because an internal mining division would be subject to moral hazard and underprovide effort. It further requires that contractual remedies, such as increasing the contract length or boosting purchase commitments are insufficient to make arm's length collaboration self-sustainable. The alternative to vertical integration is definitely not only to transact on spot markets governed by price competition.

Table 2: Examples of make-or-buy in the (empirical) literature

Ex-post transaction costs (1)	Dominant marginal returns (2)	Contracts / Complexity (3)	Make or Buy prediction (4)
(a) TCE, e.g. Monteverde and Teece (1982), Joskow (1985)			
High	Not supplier	Incomplete / High	**Make**
Low	Not supplier	Incomplete / High	**Buy**
(b) PRT, e.g. Antràs (2003), Nunn and Trefler (2013), Van Biesebroeck and Zhang (2015)			
High	**Buyer**	Incomplete / High	**Make**
High	**Supplier**	Incomplete / High	**Buy**
(c) Contracting flexibility, e.g. Bajari and Tadelis (2001), Levin and Tadelis (2010)			
Intermediate	Intermediate	**A choice / High**	Buy → **Cost-plus**
Intermediate	Intermediate	**variable / Low**	Buy → **Fixed-price**

Applications that find support for the PRT predictions also make implicit assumptions. For example, Antràs (2003) finds a positive relationship at the industry level between the fraction of international trade transactions taking place within firm boundaries and the capital intensity. In his model, firms' headquarters provide the capital inputs in production and choose to conduct transactions with an arm's length supplier or through a foreign subsidiary. A high capital intensity indicates that the supplier's contribution to surplus creation is low and there is less need to choose an outside supplier that has better investment incentives. This prediction is conditional on the inability to contractually specify, monitor and enforce input provision by the outside supplier or the in-house division. The ex-post control that ownership provides is necessary to provide incentives. At the same time, it has to be the case that the two parties are bound together and cannot easily go their own way if negotiations break down, i.e. the sunk investments are transaction-specific.[7] Nunn and Trefler (2013) verify this maintained hypothesis in Antràs (2003) by measuring the relative capital intensity of the buyer's versus the supplier's industry using only a subset of the capital stock. They show that building-intensity does not predict vertical integration, but machinery-intensity does.

[7] Lileeva and Van Biesebroeck (2013) highlight the distinction between the specificity of investments, which influence the size of the surplus the firms bargain over, and the ease of appropriation of sunk investments by the controlling firm, which influences the impact of ownership on the relative bargaining position. The organizational form only depends on the relative marginal contributions of the two firms if specificity is sufficiently high and ease of appropriation is high enough, but not perfect as it would entirely destroy incentives for an in-house divisions.

The international trade literature contains many more examples that rely on the PRT to generate predictions on the structure of trade or on the decision to offshore an input. Van Biesebroeck and Zhang (2014) relate the maturity of a product to the likelihood of foreign sourcing, assuming that production processes become less high-skill (design) intensive and more low-skill (production) intensive as products mature. As low-skill inputs become more important, the cost advantage of producing in a low-wage country eventually becomes crucial. They again assume that inputs are transaction specific and ex-post transaction costs are high, which is not implausible for automobile parts that are often customized, and that contractual solutions to provide investment incentives are difficult to enforce internationally.

Such implicit conditions are equally important in other contexts that study the determinants of organizational form. For example, Bajari and Tadelis (2001) consider alternative contracting options in construction where the buyer can provide a comprehensive design at a cost. Sometimes, e.g. for simple projects, it is optimal to provide such design and sign a fixed-price contract which makes the contractor the residual claimant. It reduces ex-post transaction costs, but raises the ex-ante costs of the buyer. For more complex projects, providing a comprehensive design, i.e. completing the contract, becomes too costly. A buyer will instead offer a cost-plus contract, where future adjustments are simply compensated and the buyer remains residual claimant. Modeling the trade-off between the two alternative contracts, fixed-price or cost-plus, as a function of the complexity of the project implicitly assumes that it is inefficient for the buyer to bring the project in-house and hire the contractor as an employee and that these contracts can be enforced without holdup and costly delays.

In another example, Levin and Tadelis (2010) model outsourcing of city services as determined by the difficulty of specifying, enforcing, and adjusting performance standards. They implicitly assume that the city employees have the ability to perform the service in-house and that the cost of switching to an alternative service provider is too high to be a viable threat to provide performance incentives without having to move production in-house.

Many studies explicitly discuss the necessary conditions for the prediction of interest to hold, but in the empirical work they are often ignored or assumed to be satisfied in the specific setting chosen for the analysis. As we want to learn in which circumstances alternative theories apply or which model generates the most powerful predictions, it becomes necessary to condition explicit on other factors. In addition, we anticipate that variables that are able to predict the make-or-buy decision when some complementary assumptions are satisfied, do not lose their predictive power entirely in other circumstances. Table 3 contains two examples that illustrate how we can extend the reasoning behind make-or-buy predictions to generate predictions on the nature of collaboration with external suppliers.

Consider first the TCE logic. When the buyer provides at least some of the (transaction-specific) investments, in-house production is a possibility and it will be chosen if the ex-post transaction costs are sufficiently high. The sourcing of automotive parts in Monteverde and Teece (1982) did require some buyer investment (by the nature of the final product) and engineering effort was a reasonable proxy for the magnitude of ex-post transaction costs. This situation is depicted in the first two lines of Table 3.

If, however, the supplier or the in-house component division has to provide all engineering effort, in-house production would be highly inefficient in terms of lost incentives for the supply division. We expect such components to be outsourced, but still expect that the extent of ex-post transaction costs influences the nature of the relationship between the buyer and supplier. With high costs, the buyer is likely to interact closely with the supplier to facilitate the resolution of any conflicts that might arise when changes need to be implemented. In the data, it will be recorded as an outsourced input, but even though the supplier is an independent legal entity, in practice it can operate with some of the features of an in-house division.

Table 3: Forms of governance when contracts are incomplete

Ex-post transaction costs (1)	Dominant marginal returns (2)	Theory predicts (3)	Data (4)
(a) TCE logic:			
High	Buyer	**Make**	Make
Low	Buyer	**Buy** (*Captive*)	Buy
High	Supplier	**Make-like** (*Relational*)	Buy
Low	Supplier	**Buy***	Buy
(b) PRT logic:			
High	**Buyer**	**Make**	Make
High	**Supplier**	**Buy** (*Relational*)	Buy
Low	**Buyer**	**Make-like** (*Captive*)	Buy
Low	**Supplier**	**Buy***	Buy

Note: * When the PRT and TCE logic agrees, buyers will form *Market* or *Modular* relationships (see below).

All carmakers tend to have several preferred tier-1 suppliers that they collaborate with repeatedly on many of their models. Buyers and suppliers station some of their employees at each other's premises, they coordinate their IT systems in order to facilitate joint design and just-in-time, even just-in-sequence deliveries to the assembly line. From a TCE perspective such a relationship is not all that different from making a part in-house. We will call this option a *Relational* mode of governance with an external supplier.[8]

A similar reasoning is possible from a PRT perspective. If ex-post transaction costs are high, the relative importance of investments will have predictive power for the make-or-buy decision. The importance of transaction costs makes close and repeated collaboration preferable, but only when the buyer investment dominates will it be optimal to bring the activity in-house. If suppliers make all crucial investments, an external supply relationship is preferable to give stronger investment incentives. Collaboration will still be close, however, leading to the *Relational* mode of governance.

In the reverse situation, when ex-post transaction costs are low, it will not be worthwhile to bring the transaction in-house. When the buyer makes the most important investments, it will look for ways to adjust the supplier relationship to help safeguard its investments and increase its bargaining position. One way to achieve this is by prohibiting the supplier to work for other firms.[9] Even though the supplier has control over its own investments, it has no ongoing relationships with other carmakers that could provide an outside option to use as bargaining chip in a negotiation. From the PRT perspective such a *Captive* relationship gives the buyer almost the same benefits as vertical integration.

In situations where the two theories give opposing predictions, we expect inputs to be outsourced, but the form of supplier governance to match the situation. If only the PRT logic suggests in-house production because buyer investments dominate, suppliers can be made captive, a make-like form of buying from the perspective of bargaining power. If only the

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[8] Helper (1991) describes how the US automotive industry has gone from very close collaboration between carmakers and suppliers at the start of the twentieth century, and again starting in the 1980s, while the intervening post-war period was characterized by greater prominence of in-house production and arm's length relationships with the remaining outside suppliers. The close collaboration was characterized by intense exchange of information and long-term relationships with outside suppliers.

[9] Ahmadjian and Oxley (2011) describe the close collaboration in the Japanese automotive industry where carmakers often take an equity position in their suppliers, but also help close suppliers to smooth production if demand fluctuates.

TCE logic suggests in-house production because ex-post transaction costs and the risk of holdup is large, we expect a tight, collaborative relationship with the supplier. Even though it is an independent firm, the collaboration is structured as with an in-house division to facilitate conflict resolution and adaptation.

2.2 Choosing between many forms of governance

When contracts are incomplete, firms can structure collaborations with their suppliers in a way suit the situation, broadening their options beyond the simple make-or-buy dichotomy. The four possibilities in Table 3 all assume that contracts are incomplete and we show them as a straightforward 2-by-2 trade-off in the top panel of Table 4.

When transactions are not too complex and ex-post transaction cost considerations or investment incentives can be dealt with contractually, or firms can modify features of transactions to make them contractible, firms have even more options. Rather than tailor the supplier governance to the situation, they can tailor the contract. In the bottom panel of Table 4, we show choices between different contracts in the same framework. As we do not observe contract choices in our dataset, in the empirical analysis we combine all buyer-supplier relationships governed by appropriate contracts into a single *Market* type of relationship.

Table 4: Different relationships by contract or by organizational form

Incomplete contracts →

		Ex-post transaction costs (TCE)	
		High	Low
Dominant Marginal Returns (PRT)	Buyer	Make	Buy (*Captive*)
	Supplier	Buy (*Relational*)	Buy (*Modular*)

Complete contracts →

"Buy" at fixed price		**Ex-post transaction costs (TCE)**	
		High	**Low**
Dominant Marginal Returns (PRT)	Buyer	Contract specifies conditional obligations	Spot market
	Supplier		Performance contract

If every single aspect of a transaction makes in-house production unnecessary—(i) complexity is low and contracting is possible, (ii) the supplier makes the key investments, and (iii) ex-post transaction costs are low, for example because assets are not transaction-specific—the buyer can simply purchase inputs on the spot market. If supplier investments are more important, but still verifiable, they can be described in a performance contract. It specifies the necessary effort or investment by the supplier necessary to achieve the desired input quality and the buyer only pays when contractual obligations are met. If ex-post transaction costs are high, the risk of holdup can be resolved by contractually specifying the conditional obligations of both buyer and supplier in all states of the world. If the transaction is sufficiently simple that the relevant uncertainties that could trigger a need for adjustments can be anticipated, the appropriate response can also be anticipated and included in the contract.

Naturally, dealing contractually with investment incentives and potential holdup is limited. Contractibility is determined by the complexity of the transaction and complete contracts will only be available for relatively simple transactions. If complexity is too high and a complete contract is not available, the buyer will need to tailor its relationship with the supplier to achieve satisfactory collaboration, as discussed earlier.

In principle, a relational contract can replace a formal contract (Baker, Gibbons and Murphy 2002). Rather than relying on an outside court for enforcement, the value in the ongoing relationship serves to self-enforce to contract. Payments can be specified to reward the supplier even for actions that are not verifiable by outsiders and the supplier will comply as long as the benefit of deviating from this implicit contract is lower than the expected net present value of the future stream of payoffs within the relationship. Naturally, such a relational contract is limited to situations where both parties' interests diverge not too far and also not their assessments of the future value of the relationship.

Our predictions are closely related to the highly influential theory of Gereffi et al. (2005) on governance in global value chains (GVC). They rely on distinct literatures from management and economic geography, but we can line up our predictions with theirs. They start from three characteristics of a transaction: (i) how easy it is to objectively define performance characteristics, (ii) the (technological) capabilities present in the supply base, and (iii) the complexity of a transaction.

The TCE notion of ex-post transaction costs is represented in the GVC theory by the codifiability of performance requirements. If it is possible to describe and for an outside court to verify whether an input meets the required quality, is reliable, and is delivered on time,… ex-post transaction costs will be low as the supply contract can specify these performance features rather than the product characteristics or the suppliers' actions and investments. While the nature of the production process might still bind the buyer and supplier together, e.g. due to transaction-specific assets, the residual claims when adjustments need to be made can be assigned in advance by explicitly determining the performance requirements. If a technological change or unanticipated difficulty makes a component fall short of its required performance, the supplier will need to absorb the necessary adjustment costs. If a design change in the rest of the vehicle requires an adjustment in the functionality of a component, the supplier will need to be compensated for this. If such adjustments or the costs they will entail are difficult to predict, codifiability is low and ex-post transactions costs are high.

The key predictor in the PRT is the marginal return of a supplier's investment to the joint surplus relative to the marginal return of the buyer's investment. It is replaced in the GVC theory by the existence or not of strong capabilities in the supply base, which need to be judged relative to the requirements of the transaction as is the case for the other dimensions. Capabilities are also deemed to be low if a buyer provides some crucial input and supplier investments cannot substitute for this, for example due to informational differences. While the PRT explicitly considers the relative importance and focuses on marginal effects in terms of surplus creation, the existence of a supply base with sufficient capabilities is more of an equilibrium consideration. If supplier investments are dominant and independent suppliers are incentivized, we expect the supply base to generate the necessary capabilities.

If all three characteristics can take a high or a low value, it leads to eight possible situations that in principle each require a distinct optimal type of governance. Gereffi et al. (2005) argue, however, that the first two dimensions loose much of their importance if transactions are not complex, in which case they are satisfied almost automatically. This is similar to our argument that the completeness of a contract is inversely related to the complexity of a transaction. The GVC theory predicts that low complexity by itself will lead to market transactions, irrespective of the codifiability or capabilities. In our case, we do not observe firms' contract choices and cannot distinguish between the different situations in the bottom panel of Table 4 from the patterns in the buyer-supplier interactions. Hence, we study the same five governance types that the GVC theory considers and we already borrowed their terminology of governance types as listed in the first column of Table 5.

Table 5: Predictions of the Global Value Chains theory of Gereffi et al. (2005)

↓ GVC terminology of governance types	Contract incompleteness ↓ **Complexity** of the transaction	Inverse of ex-post transaction costs ↓ **Codifiability** of performance requirements	Supplier marginal returns ↓ **Capability** of the supply base
Market	Low	N/A (High*)	N/A (High*)
Modular	High	High	High
Relational	High	Low	High
Captive	High	High	Low
Hierarchy	High	Low	Low

Note: * High codifiability and High supplier capability for Market governance has to be interpreted in light of the Low complexity of the transaction. They are not necessarily higher than the low values that are indicated for either dimension further below in the table in the case of complex transactions.

We call the group of non-complex transactions or situations that can be governed by appropriate contracts *Market* transactions. At the other extreme are in-house transactions, governed by *Hierarchy*; and the *Relational* and *Captive* governance modes have already been discussed. The one governance type left to discuss is *Modular*, where complexity is high, but supplier capabilities and performance codifiability are high as well. The complexity makes spot market transactions unattractive, but both the TCE and PRT characteristics favor outsourcing. The supplier should have control over its investment to elicit high effort, or put differently, the unique capabilities in the supply base are more important for component quality than the buyer's inputs. Low asset specificity or a low likelihood of requiring future adaptations limit the ex-post transaction costs, or put differently, the buyer can specify requirements in terms of well-defined performance standards, leaving the supplier to decide on the actions, investments, and technology choices to meet these standards. Sturgeon (2002) describes how the nature of buyer-supplier interaction in the electronics industry often fits this situation. The nature of technology in this industry, e.g. the ability to exchange electronic files that specify designs and interconnections, facilitates collaboration on highly complex components through arm's length supply relationships.

3. Data

Because the empirical model is shaped to a large extent by the available data, we first describe the structure and content of our unique transaction-level dataset. It is based on information of supply contracts for individual parts or larger components in the automotive industry. The data comes from *SupplierBusiness*, a consulting firm, and covers transactions from models that entered production between 1993 and 2012. It includes all major carmakers and global first-tier suppliers. In addition, it includes contracts awarded to more than a thousand small and medium size supplier firms located in Europe and North America.

In total, we observe 64 unique buyers, defined as an original equipment manufacturer (OEM) in one of the two regions, Europe or North America.[10] We further observe 2,205 unique suppliers, defined as the product division of a supplier firm in one of the two major geographic regions. Finally, contracts are observed for 350 models and 213 unique parts, which are defined by *SupplierBusiness* using a nested component classification system. A unit of observation in our analysis is a transaction, i.e. a unique combination of a buyer, a supplier, and a product. We only observe a subset of transactions, but with 57,354 observations out of a potential total of 74,550 (350 x 213) coverage is relatively complete.

In the analysis we use four dependent variables, which each proxy for a different type of supplier governance. They are constructed based on market shares within all observed transactions along various dimensions, e.g. by supplier, by buyer, by product,... Two of the key explanatory variables (codifiability and complexity) are constructed based solely on the structure of the parts classification. The construction of the dependent variables and explanatory variables of interest are described in detail in the next section. We include contract length, as proxied by the number of months between the start and end of production of a car model, as control variable in the regressions. Longer contracts can indicate greater uncertainty in a buyer-supplier relation (Joskow, 1985).

[10] We observe 15 unique ultimate owners, which generally sell vehicles under multiple brands and in both regions. While vehicles marketed under different brands are sometimes based on common platforms, they are largely designed separately and most of the sourcing decisions on parts are taken at the brand level. Exports of vehicles between Europe and North America are relatively unimportant as most vehicles are assembled in the region where they are sold. Hence, we consider Ford-Europe and Ford-North America as separate buyers, and similarly for Volkswagen-Europe and Audi-Europe.

To construct the third explanatory variable of interest (capability) and additional control variables, we added firm-level information on OEMs and suppliers from *Amadeus*, a database with complete coverage of European firms. The matching process to the contracting data is described in more detail in Schmitt and Van Biesebroeck (2013). The *Amadeus* database contains balance sheet information, address information, and a detailed industry classification. Unfortunately, the sample is reduced quite substantially as we are only able to match the suppliers in 16,548 of the observations.

Geographic proximity is known to play an important part in both the decision to outsource and the choice of individual suppliers (Schmitt and Van Biesebroeck, 2013). We therefore include the distance from the closest supplier plant to the model's assembly plant, and from this supplier plant to the administrative office of the OEM. In addition, we include a dummy variable for the presence of a country border between the two plants, which is an important variable in the analysis of foreign direct investment. Cultural, historic, or institutional ties can also play a role in the organization of outsourcing relationships. We include a variable of cultural distance measured at the country level based on the locations of the headquarters of the supplier and buyer. The index is calculated using the survey data of Hofstede (1980) as the Mahalanobis distance over four dimensions: individualism, power distance, uncertainty avoidance, and masculinity.

We experimented with several variables to control for the production technology of the supplier, such as the total number of workers at a supplier, its capital intensity, measured as the total value of assets per worker at the plant, and a proxy for value added, defined as operating revenues over total assets. As the first two variables almost invariably became statistically insignificant if the third variable was included, we only retained that one.

4. Empirical model and variable construction

4.1 Empirical model

If the various governance types (indexed by *k*) could be unambiguously identified, as is the case when studying the make-or-buy decision, one could simply estimate a multinomial logit model at the transaction level, linking the probability of each type to the explanatory variables of interest:

$$Pr[type = k] \sim f(\beta_{1k} * complex + \beta_{2k} * codify + \beta_{3k} * capable + controls).$$

Unfortunately, as governance types are not directly recorded, we need to rely on observable proxies to identify them. It might even be the case that a buyer-supplier relationship is of an intermediate form and does not correspond exactly to one of the governance types listed in Table 5. Therefore, we do not partition relationships exhaustively in four groups, but we calculate for each transaction four continuous variables that we argue to be monotonically related to one of the governance types. Note that transactions that use *hierarchy* or in-house production (the fifth governance form) are by construction excluded from our sample. We base the proxy variables on the extensive set of case studies in the global value chains literature that describe differences in organizational forms and the environments most suited for each form. The regressions we estimate take the following form:

$$y_{bmsp}^{k} = \beta_{1k} * complex_p + \beta_{2k} * codify_p + \beta_{3k} * capable_s + controls + \epsilon_{bmsp}, \quad (1)$$

with $y^k = \{market_{sp},\ captive_{sb},\ relational_{sbp},\ modular_{sb}\}$. The dependent and explanatory variables vary at the levels indicated by the subscripts in equation (1) and we describe in the next sub-sections how they are constructed and what motivated these choices.

We will estimate four sets of coefficients β_1, β_2, and β_3, one for each governance type, using the full sample of transactions defined by the buyer, model, supplier, and product (*bmsp*).[11] When we use one dependent variable, say $y^k = market$, all transactions that are sourced using one of the three non-market types are expected to have relatively low values for this dependent value. Only when a characteristic is high for market and low for all other types, or vice versa, do we expect a systematic relationship between the characteristic and the dependent variable for market. From Table 5 we see that this is for example the case for complexity, which is expected to be low for market and high for captive, relational, and modular, and we expect a negative sign on the complexity variable in the market regression. It is not the case for codifiability or capability, which are expected to be high for market transactions, but also for some of the other types of transactions, and we have no clear sign predictions for them. The only other unambiguous sign predictions are a negative effect on capability in the captive regression and on codifiability in the relational regression.

[11] Note that observations are identified by *bm*—a specific model produced by a buyer—but explanatory and control variables only use information on the buyers, ignoring individual models. In the construction of the dependent variables we always sum over all models produced by a buyer.

Pairwise comparisons between types generates several more unambiguous predictions. For example, if we had a way to limit the sample to only market and captive transactions, we would additionally expect a positive relationship between capability and the likelihood of a market transaction because the theory predicts $\beta_{3market} > \beta_{3captive}$. One way to investigate these pairwise predictions is to take the difference between the equations for two governance types and estimate regressions of this form:

$$y_{bmsp}^{k} - y_{bmsp}^{l} = (\beta_{1k} - \beta_{1l}) * complex_p + (\beta_{2k} - \beta_{2l}) * codify_p$$

$$+ (\beta_{3k} - \beta_{3l}) * capable_s + controls + \tilde{\epsilon}_{bmsp}. \qquad (2)$$

For example, using as dependent variable $\left(market_{sp} - captive_{sb}\right)$ makes it possible to test whether the prediction $\left(\beta_{3market} - \beta_{3captive}\right) > 0$ holds.

Alternatively, we can also make pairwise comparisons if we assign each transaction to either of the two types, depending on the value it attains in the distribution of the two dependent variables. Pairwise comparisons can then simply be performed with a probit regression on the sub-sample of transactions assigned to one of the two types under consideration. To avoid misclassifying transactions where the best fit with either of the two types is ambiguous, we omit transactions that have values above the median of the dependent variable for both types or have values below the median for both variables. We only keep transactions with a high value for one dependent variable and a low value for the other. We then estimate the following probit regression:

$$Pr\left[y_{bmsp}^{k} > p_{50\%}^{k} \ \& \ y_{bmsp}^{l} < p_{50\%}^{l}\right] =$$

$$\Phi\left(\beta_{1kl} * complex_p + \beta_{2kl} * codify_p + \beta_{3kl} * capable_s + controls\right), \qquad (3)$$

with $\Phi(.)$ the normal distribution function and $p_{50\%}^{k}$ the median value for variable y_{bmsp}^{k} and similarly for type l. The sample excludes transactions where y^k and y^l are on the same side of their respective medians.

4.2 Dependent variables

To define the dependent variables that proxy for governance types in supplier sourcing, we exploit the relative frequency that transactions in the dataset involve the same buyer, supplier, or product, or the same buyer-supplier combination, etc. We could calculate these market shares simply by counting transactions, which gives the variables the interpretation of a probability. However, effects for the explanatory variables of interest were estimated more precisely, but almost always with the same sign, if we weighted each transaction by the projected total production volume of the model at the time of the contract (q_{bmsp}).

We need a proxy variable that is monotonically increasing in the likelihood that a transaction is of a given governance type. As we want an approach that works generically, we propose a ratio of two shares for each governance type, where the case literature has guided us in the selection of the different shares in the numerator or denominator. Intuitively, we aim to measure how concentrated contracting is along the dimension intuitively most closely connected with a particular governance type and normalize this by the concentration along some other dimension.[12]

The different market shares that enter these calculations, which are listed in the third column of Table 6, are the total market shares of the buyer, seller, or product over the entire market (σ_b, σ_s and σ_p), the market share of a particular buyer-supplier pair over all products they exchange (σ_{bs}), and the same share limited to a single product *p* (σ_{bsp}), but still summing over all models. The reasoning why a large value of each dependent variable maps into a high likelihood for a particular governance type is discussed in turn.

Table 6: Definitions of the dependent variables that proxy for the form of governance

Governance type	Interpretation	Definition	
Captive	Supplier *s* has a low market share while buyer *b* has a high market share.	$-\ln\frac{\sigma_s}{\sigma_b} =$	$\ln\frac{\sum_m \sum_s \sum_p q_{bmsp}}{\sum_b \sum_m \sum_p q_{bmsp}}$
Relational	The specific buyer-product relationship *bp* accounts only for a small fraction of the total market share of supplier *s*.	$-\ln\frac{\sigma_{bsp}}{\sigma_s} =$	$\ln\frac{\sum_b \sum_m \sum_p q_{bmsp}}{\sum_m q_{bmsp}}$
Modular	Supplier *s* has a relatively high market share compared to the set of products ('module') that it supplies to a buyer *b*.	$+\ln\frac{\sigma_s}{\sigma_{bs}} =$	$\ln\frac{\sum_b \sum_m \sum_p q_{bmsp}}{\sum_m \sum_p q_{bmsp}}$
Market	A low market share for supplier *s* relative to the total market share of product *p*.	$-\ln\frac{\sigma_s}{\sigma_p} =$	$\ln\frac{\sum_b \sum_m \sum_s q_{bmsp}}{\sum_b \sum_m \sum_p q_{bmsp}}$

[12] As we divide two market shares in each definition, the implicit normalization of the summed quantities in the denominator of both shares always cancel out.

Note: The subscripts *bmsp* stand for buyer, model, supplier, and product, respectively. The sum of quantities in the numerators and denominators become market shares after dividing by the quantity for the entire market.

Captive relationships will be characterized by a small market share for the supplier relative to the buyer it sells to, i.e. σ_s/σ_b is low and the negative of the logarithm of this relative market share—the dependent variable shown in Table 6—is high (Ahmadjian and Oxley, 2006).[13] In Relational governance the supplier is independent and sought after for its unique expertise. This expertise tends to be at the level of a product which is often uniquely tailored to a buyer's needs (Bensaou, 1999; Pietrobelli and Rabellotti, 2011). As a result, the share of each buyer-product share in the supplier's overall sales is limited, i.e. σ_{bsp}/σ_s is low (Sturgeon, Van Biesebroeck, and Gereffi, 2008). A supplier will operate with the same independence in Modular relationships, but here one particular product can account for a large share of a supplier's market share (Sturgeon, 2002). The entire business of each buyer will still account for a relative small fraction of a supplier's overall market share, but individual components might dominate a buyer-supplier relationship (Humphrey, 2003). Market relationships will have low supplier market shares relative to the overall product market (Stigler, 1951). Competition is high for relatively common products.

Table A.1 in the Appendix shows the mean and standard deviations of all dependent variables, as well as for the explanatory and control variables.

4.3 Explanatory variables

We also need proxies for the three characteristics of transactions: codifiability, complexity, and capability. Importantly, we use information on the type of component or supplier, but not on the buyer or the buyer-supplier interaction, as that information was used to construct the dependent variables. It mirrors the approach in the seminal study of Monteverde and Teece (1982) who used expert surveys to independently assess the engineering requirements of the design and production of car components as a predictor of outsourcing decision.

[13] In some industries, e.g. the apparel industry, supply chains can be buyer-driven leading to captive upstream suppliers, or producer-driven leading to captive downstream retailers (Gereffi, 1999). In the automotive sector only the former type is relevant.

Complexity

To ascertain whether a part is complex or not, we exploit the hierarchical structure of the component classification as defined by the data provider, *SupplierBusiness*. We measure the complexity of individual parts by the number of sub-categories contained in the module that the part belongs to. Our objective is not to capture the technological complexity of production, but the extent and intensity of interactions with the buyer and with other suppliers working on parts that need to be assembled into the same module. If such linkages are extensive, suppliers face more uncertainty about possible future modifications. It makes it more difficult to incorporate all eventualities in a contract or makes it more costly to provide a complete design, in the language Bajari and Tadelis (2001).[14]

We count the number of sub-categories in each module and all parts that belong to that module receive the same value.[15] As we do not want to give this simple count a cardinal interpretation of complexity, we stick close to the theory and map the complexity proxy into a dummy variable that indicates whether a value is below or above the sample median. Table A.1 in the Appendix shows the means and standard deviations of all three explanatory variables. 58% of transactions involve products that are part of a complex module. It differs from an exact 50-50 split because approximately 10% of the transactions in the dataset have a number of sub-categories exactly equal to the median value.

Codifiability

Levi, Kleindorfer and Wu (2003) provide a useful, but narrow definition of codifiability as "the ability to precisely characterize in electronic format the nature of the product/service contracted for, including delivery requirements and any other contractual/fulfillment requirements that may pertain to a specific transaction, in a manner understandable to relevant parties." (Levi et al., 2003, p. 79) This has two dimensions: (i) the codifiability of the component as such and (ii) the codifiability of its interfaces with other parts of the car."

[14] One way to alleviate uncertainty would be through product standards, hence we predict different governance approaches for complex transactions depending on the codifiability.

[15] An even simpler indicator we experimented with classifies components as either stand-alone parts or as sub-assemblies or larger modules that consist of several parts and need to be assembled themselves. Results were qualitatively similar using this alternative measure of complexity.

More generally, a component is codifiable if the buyer is able to specify in advance and in a readily verifiable way the performance characteristics a part has to meet. The supplier will produce and possibly also design it by choosing cost-effective technologies and input bundles to meet performance requirements. If a part occurs in several sub-assemblies that occur in different places of a vehicle, it is not very specific to a single module or application. Such widespread use of a component makes it more likely to appear in several outsourcing relationships and standardization of its performance requirements will be more valuable. It can generate scale economies and increase competition. While the components might still be very complex, for example because they interact with many other parts, the standardization of functionality can make it less model-specific and lower the scope for ex-post holdup by the supplier and the buyer.

To operationalize this insight, we again rely on hierarchical way the automotive experts of *SupplierBusiness* have organized the components in the dataset. Transactions are first classified into several broad *areas*, such as the engine, body & trim, interior, or chassis. Within each area there is a second level of sub-categories by function, called *modules*, such as a bumper, braking system, console, etc. In the third level of sub-categories, all *components* in a module are partitioned in unique categories that share few characteristics with other third-level components. The more complex a module is, the more groups there are at this third level. Components with standardized characteristics are sometimes used in several modules (often produced by different suppliers), examples include bearings, gaskets, sensors, etc. One measure of codifiability is a simple count of the number of times a component occurs in distinct third-level sub-categories over the entire group of 350 models that we observe. To make the variable less sensitive to outliers and facilitate interpretation in the regressions, we again code it as one or zero, relative to the median value.

We experimented with an alternative measure using information from outside our dataset. A component was classified as codifiable if it was covered by AUTOSAR (Automotive Open System Architecture). This is a collaboration of car assemblers and suppliers to develop open industry standards. The initiative addresses the rapidly increasing sophistication of electric and electronic systems in cars which limits the exchange of applications between assemblers and suppliers. An objective is to move away from proprietary solutions, prevalent in the car industry, and to optimize the interfaces of and interactions between components.[16] Results using this variable had almost always the same signs as the benchmark codifiability variable, but it reduced the sample size as not all components could be classified unambiguously.

Capability

The third explanatory variable to predict governance is supplier capability. As in the literature on equilibrium market dynamics, we measure it as the size of a supplier conditional on its age. That literature on market selection explains firms' growth from differences in innate productivity which firms discover through their own market activities. More productive firms will gradually discover their ability, grow over time, and survive for a longer period. This selection mechanism is highly relevant for the evolution of the automotive industry over the last 20 years, as it has consolidated through mergers and supplier exit in the 2008-2009 recession. The industry also globalized notably, which allowed the most efficient firms to increase in size (Sturgeon et al., 2008).

Haltiwanger, Jarmin and Miranda (2013) show that it is important to control for firm age when studying firm growth as firms need time to reach their desired size. A related literature on firm capability and learning argues that firms compete on the basis of internal resources that also take time to develop (Penrose, 1959). These capabilities are not only technological sophistication, but can be any skill that helps a firm prosper and survive, e.g. cost efficiency. As R&D expenditures also increase strongly with firm size, parts outsourced to large suppliers are more likely to require important investments on the suppliers' side.

We measure size using turnover (operating revenues in 2007) and divide by the age of the main EU branch or regional headquarters, both observed in the *Amadeus* dataset. We prefer to measure firm size by sales rather than R&D expenditures as the latter variable would also capture the complexity of the components a firm produces. We again make the variable binary by comparing it with the sample median. While the correlation between complexity and codifiability, which are both based only on the component classification, is relatively high, the capability measure is almost orthogonal to the other two variables.

[16] Further information on the AUTOSAR initiative can be found at http://www.autosar.org/.

5. Results

We now present the estimation results for the different dependent variables, starting with the effects estimated using equation (1). At the top of Table 7 we summarize the theoretical predictions on the relationships between each of the four types of governance and the three key explanatory variables. The shaded areas highlight the instances where there is an unambiguous sign prediction on the full sample of transactions. This occurs when only one governance type is associated with a low value of a characteristic.

In the first panel with results, we only include the characteristic that can be unambiguously related to a governance type in the regressions. All three predictions are strongly supported. Market governance is negatively related to complexity, in line with the prediction that the other three governance modes are only chosen if complexity is high. Similarly, the captivity proxy is negatively related to supplier capability and the relational proxy negatively related to codifiability. Each of the three point estimates is significantly different from zero. There is no unambiguous prediction for modular governance, as at least one other governance type also predicts a high value for each of the three characteristics. Only modular and market relationships combine high capability and high codifiability, but in market relationships these characteristics are not necessarily high in an absolute sense, as transactions are not complex. We do find the proxy for modular governance to be positively correlated with a dummy variable for simultaneously high values of capability and codifiability.

Results in the next panel confirm these findings for specifications that include all three explanatory variables simultaneously. The three shaded point estimates are slightly lower (in absolute value), but that is expected given the strong correlation between complexity and codifiability. For modular governance, all three signs are estimated to be positive, but only the complexity variable shows a statistically significant coefficient. Including all control variables in the regressions, results reported in the lowest panel, does not change any of the signs of interest and raises the statistical significance of several estimates. We now discuss the results in greater detail by governance type.

Table 7: Results by governance type

	Market	Captive	Relational	Modular
Complexity	Low	High	High	High
Capability	High	Low	High	High
Codifiability	High	High	Low	High

	Market (1a)	Captive (2a)	Relational (3a)	Modular (4a)
Complexity	-0.628*** (0.0212)			
Capability		-0.0666** (0.0265)		
Codifiability			-0.500*** (0.0298)	
Capability & Codifiability				0.0721** (0.0353)
Observations	16,537	16,159	15,331	15,805

	Market (1b)	Captive (2b)	Relational (3b)	Modular (4b)
Complexity	-0.545*** (0.0325)	-0.458*** (0.0424)	0.373*** (0.0427)	0.0923** (0.0360)
Capability	-0.00553 (0.0201)	-0.0580** (0.0263)	0.0906*** (0.0261)	0.0358 (0.0223)
Codifiability	0.119*** (0.0350)	-0.0392 (0.0457)	-0.192*** (0.0459)	0.00011 (0.0388)
Observations	16,537	16,159	15,331	15,805
Adjusted R^2	0.051	0.015	0.023	0.001

	Market (1c)	Captive (2c)	Relational (3c)	Modular (4c)
Complexity	-0.530*** (0.0366)	-0.501*** (0.0480)	0.406*** (0.0465)	0.110*** (0.0399)
Capability	-0.136*** (0.0241)	-0.286*** (0.0316)	0.409*** (0.0306)	0.182*** (0.0262)
Codifiability	0.0675* (0.0391)	-0.102** (0.0512)	-0.121** (0.0496)	0.00372 (0.0425)
Distance	0.0768*** (0.00734)	-0.0221** (0.00961)	-0.00303 (0.00935)	-0.00921 (0.00796)
Hofstede culture	-0.117*** (0.0232)	0.380*** (0.0304)	-0.260*** (0.0294)	-0.586*** (0.0252)
Border effect	0.0712*** (0.0271)	-0.000509 (0.0355)	-0.00480 (0.0344)	0.109*** (0.0295)
Contract length	-0.00703*** (0.000588)	-0.00335*** (0.000771)	0.0131*** (0.000748)	0.00739*** (0.00064)
Value added	-0.0449*** (0.00194)	-0.0351*** (0.00254)	0.0475*** (0.00245)	0.0170*** (0.00210)
Observations	12,341	12,341	12,241	12,241

Adjusted R^2	0.133	0.051	0.096	0.071

Note: Table 6 contains the definitions of the (continuous) dependent variables. Shaded areas refer to coefficients with theoretically unambiguous sign predictions. All regressions include a constant term (not reported). Standard errors in brackets; ***, **, * indicate statistical significance at the 1%, 5%, 10% level.

Market governance

As discussed, the proxy for market governance shows a strong negative relationship with complexity, but the theory also predicts a high level of codifiability and high supplier capabilities. To some extent, this is almost by construction as the reverse would be difficult to imagine for transactions that are not complex. We do not have an unambiguous sign prediction for capability because transactions with a low value for the market proxy could be relational or modular, in which case capability is also predicted to be high. The same holds for the codifiability variable, modular or captive transactions are also predicted to have high codifiability.

We resolve this ambiguity by making pairwise comparisons in in columns (4) and (5).. The theoretical predictions are again summarized at the top and unambiguous sign predictions, which are now a lot more numerous, are shaded. Results in panel (a) for estimates of equation (2) use the difference between two continuous governance proxies as dependent variable, while results in panel (b) use dummy dependent variables according to equation (3). There are only two instances where a sign differs in the two panels and the coefficients are never statistically significant.

In the first column, we compare market explicitly to captive. In addition to the negative sign on complexity, as before, we now also find a positive sign on capability as captive suppliers are expected to have low capability. The positive effect is estimated very precisely in both panels. The effect on complexity, however, becomes insignificant if we compare explicitly with captive and even receives the wrong sign in panel (b). It suggests that transactions under market governance are much less complex than relational or modular transactions, but not so different from captive transactions. In column (2) we compare market explicitly to relational and we find the expected positive sign on codifiability. We already found this last effect in the unconditional comparison in Table 7, but the point estimates are now much higher, at 0.186 and 0.225 in the two panels, compared to 0.067 before. The results indicate that the ability to standardize non-complex components is especially high in comparison with transactions under close, relational governance.

Table 8: Results for pairwise comparisons

Theoretical predictions

	Market vs. Captive	Market vs. Relational	Market vs. Modular	Captive vs. Relational	Captive vs. Modular	Modular vs. Relational
Complexity	Low v. High	Low v. High	Low v. High	High	High	High
Capability	High v. Low	High	High	Low v. High	Low v. High	High
Codifiability	High	High v. Low	High	High v. Low	High	High v. Low

(a) Estimation results for difference of (continuous) dependent variables

	Market – Captive (1a)	Market – Relational (2a)	Market – Modular (3a)	Captive – Relational (4a)	Captive – Modular (5a)	Modular – Relational (6a)
Complexity	-0.0293	-0.940***	-0.639***	-0.911***	-0.606***	-0.289***
	(0.0434)	(0.0735)	(0.0609)	(0.0884)	(0.0831)	(0.0300)
Capability	0.151***	-0.544***	-0.319***	-0.704***	-0.481***	-0.232***
	(0.0285)	(0.0483)	(0.0400)	(0.0581)	(0.0546)	(0.0197)
Codifiability	0.169***	0.186**	0.0654	0.0258	-0.0940	0.127***
	(0.0462)	(0.0783)	(0.0649)	(0.0943)	(0.0886)	(0.0320)
Distance	0.0989***	0.0796***	0.0855***	-0.0194	-0.0132	-0.00653
	(0.00869)	(0.0148)	(0.0122)	(0.0178)	(0.0166)	(0.00603)
Hofstede culture	-0.497***	0.140***	0.469***	0.637***	0.962***	-0.326***
	(0.0275)	(0.0465)	(0.0385)	(0.0559)	(0.0525)	(0.0190)
Border effect	0.0717**	0.0723	-0.0381	-0.0175	-0.122**	0.121***
	(0.0321)	(0.0543)	(0.0450)	(0.0653)	(0.0614)	(0.0222)
Contract length	-0.00368***	-0.0201***	-0.0144***	-0.0163***	-0.0107***	-0.00578***
	(0.00070)	(0.00118)	(0.00098)	(0.00142)	(0.00133)	(0.00048)
Value added	-0.00980***	-0.0923***	-0.0618***	-0.0833***	-0.0527***	-0.0304***
	(0.00230)	(0.00387)	(0.00321)	(0.00466)	(0.00439)	(0.00158)
Observations	12,341	12,241	12,290	12,241	12,290	12,241
Adjusted-R^2	0.051	0.130	0.105	0.078	0.059	0.108

Note: The dependent variables are the pairwise differences between the dependent variables defined in Table 6. All specifications are estimated with OLS and include a constant term which is not reported. Standard errors in brackets; ***, **, * indicate statistical significance at the 1%, 5%, and 10% level.

(b) Estimation results for discrete dependent variables

	Market vs. Captive (1b)	Market vs. Relational (2b)	Market vs. Modular (3b)	Captive vs. Relational (4b)	Captive vs. Modular (5b)	Modular vs. Relational (6b)
Complexity	0.0297	-0.458***	-0.316***	-0.441***	-0.278***	-0.568***
	(0.0700)	(0.0458)	(0.0485)	(0.0422)	(0.0425)	(0.0910)
Capability	0.384***	-0.219***	-0.106***	-0.381***	-0.245***	-0.497***
	(0.0448)	(0.0312)	(0.0331)	(0.0286)	(0.0284)	(0.0549)
Codifiability	0.347***	0.225***	0.166***	0.0477	0.00355	0.147
	(0.0728)	(0.0489)	(0.0520)	(0.0452)	(0.0454)	(0.0954)
Distance	0.152***	0.0334***	0.0544***	-0.0210**	-0.00907	-0.0331*
	(0.0164)	(0.00903)	(0.00987)	(0.00871)	(0.00865)	(0.0177)
Hofstede culture	-0.378***	0.0372	0.271***	0.255***	0.467***	-0.594***

	(0.0441)	(0.0306)	(0.0330)	(0.0277)	(0.0276)	(0.0530)
Border effect	0.0360	0.0358	-0.0432	0.0153	-0.0742**	0.217***
	(0.0528)	(0.0356)	(0.0373)	(0.0325)	(0.0325)	(0.0654)
Contract length	-0.0051***	-0.0105***	-0.0098***	-0.0070***	-0.0059***	-0.00236
	(0.0011)	(0.00078)	(0.00083)	(0.00071)	(0.00070)	(0.00145)
Value added	-0.00685	-0.0380***	-0.0393***	-0.0369***	-0.0347***	-0.0249***
	(0.00530)	(0.00289)	(0.00326)	(0.00251)	(0.00263)	(0.00447)
Observations	3,705	8,857	7,501	9,862	9,556	2,816
Quasi-R^2	0.069	0.092	0.084	0.068	0.060	0.135

Note: Reported statistics are coefficients estimates from probit regressions using dummy dependent variables as described in the text. All specifications include a constant term which is not reported. Standard errors in brackets; ***, **, * indicate statistical significance at the 1%, 5%, and 10% level.

Finally, the comparison between market and modular in column (3) shows again a strong negative sign on complexity. Both other characteristics should be high in both types of supplier relations, but the results indicate that supplier capabilities are especially high for modular, while codifiability is especially high for market. Both patterns are intuitive if we take into account that market transactions are less complex and more contractible.

Some of the control variables also show intuitive patterns. In particular, market governance works best with long-distance relationships. Distance has a positive and significant coefficient in column (1c) of Table 7 and in columns (1)-(3) of Table 8.

. Relationships that are governed by prices and contracts are more suitable for international trade and shipping over greater distances. Market governance is also systematically associated with contracts of shorter duration and contracts that generate lower value added.

<u>Captive governance</u>

Suppliers are more likely to be captive when their capabilities are low and that is indeed what we found. The relationship is stronger if control variables are included and also shows the predicted sign in all pairwise comparisons in Table 8. Note that all signs in column (1) of Table 8 would reverse if we had defined the dependent variable as $\left(captive_{sb} - market_{sp}\right)$ instead of the actual definition, $\left(market_{sp} - captive_{sb}\right)$. The positive coefficient on capability in column (1) thus has the same interpretation as the negative coefficients on capability in columns (4) and (5).

While complexity and codifiability are also predicted to be high, the point estimates on these two characteristics are both negative in Table 7. It does not necessarily conflict with the theory as captive relationships share these predictions with other governance modes. The sign on codifiability turns positive in columns (4a) and (4b) of Table 8, in line with the prediction that captive governance is more likely than relational governance if codifiability is high. But the high standard errors suggest that the distinction is not very pronounced. As already mentioned, the sign on complexity has the predicted positive sign in column (1a), for the pairwise comparison of market against captive, but the opposite sign in column (1b) works against the prediction. In general, captive and market transactions in our sample do not seem all that different. Like market governance, transactions under captive governance show much lower complexity than relational or modular transactions.

Three control variable with a systematically negative relationship with captive governance are all related to distance, both in terms of geography and national culture. Carmakers maintain much stronger control over suppliers based in culturally very distinct countries. The negative association with geographic distance and the presence of country borders is consistent with frequent co-location of captive suppliers with the assembly plant.

Relational governance

All results for relational governance correspond to the theoretical predictions. The negative coefficient on codifiability that we found in the initial regressions is confirmed by the six positive coefficients in columns (2), (4), and (6) of Table 8.[17] The initial regressions already showed an overall positive association between complexity and relational governance, but the pairwise comparisons show that complexity is higher for relational than for all three alternative governance types, not only for market. The same holds for capabilities. The theory predicts more capable suppliers in relational than in captive governance, but this even holds when comparing with the capabilities of market and modular suppliers.

To some extent this is due to the nature of technology in the automotive sector. Helper (1991), Humphrey (2003), and Sturgeon et al. (2008) all describe the difficulty of outsourcing complex modules that are frequently tailored to individual models. The complexity stems not

[17] In each of the three pairwise comparisons the dependent variable is defined to be low for relational governance.

only from customization, but also from interactions with other components in the vehicle, and the mechanical (as opposed to electronic) technology that makes it more difficult to exchange knowledge. Many of the case studies in the GVC literature discuss the automotive sector as a prime example where outsourcing of components requires close collaboration and frequent interactions. Carmakers often bring such production in-house, but that is also costly as it cuts them off from crucial knowledge of technologically advanced suppliers, while in-house divisions rarely have the same innovative track-record of external suppliers. It is not surprising that these type of close relationships are distinguished from other relationships in our sample by simultaneously high complexity, high supplier capabilities, and low codifiability.

It is also intuitive that these collaborative relationships are associated with low values of cultural distance, longer contract length, and high value added. Distances are also lower than for market or modular.

Modular governance

In the initial comparison across all governance types there were no unique predictions for modular relationships. The values for all three characteristics should be high, but that was each time also the case for at least one other governance mode. The pairwise comparisons with other governance modes that are preferred if one of the characteristics is low all generated the expected signs: a negative coefficient on complexity in the market vs. modular comparison; a negative coefficient on capability in the captive vs. modular comparison; and a positive coefficient on codifiability in the modular vs. relational comparison.

It is not directly predicted by the theory, but seems reasonable that modular governance is also characterized by more capable suppliers than in market governance and more complex components than in captive governance. Transactions governed by markets only need suppliers that are capable enough for a particular part, which does not need to be very high in absolute terms. Transactions performed by captive suppliers that have low capabilities will be more complex than market transactions, but not much more.

5.1 Implication: Supplier governance over a component’s lifecycle

The results support most of the theoretical predictions at the level of individual transactions, i.e. sourcing contracts between a buyer and supplier for a particular part. We now step back to take a look what the various governance types imply for differences between suppliers. We first classified each transaction into one of the four types, picking the type for which the proxy attained the highest value within its respective distribution. Next, we assigned each supplier to the governance type that occurred most frequently across all its transactions.

In Table 9 we show two features of suppliers allocated to each type: the profit margin as a percentage of total sales and aggregate R&D expenditures. Profit margins are by far the highest for modular suppliers and lowest for market and captive suppliers. In contrast, captive suppliers spend most resources on R&D and market suppliers the least.

Table 9: Observable difference between supplier-types

	Market	Modular	Relational	Captive
Number of firms	20	16	27	25
Profit margin (% of sales)	0.5%	6.9%	1.9%	0.7%
	(16.1)	(45.3)	(14.0)	(14.4)
R&D expenditure (thousands €)	52	204	261	349
	(55)	(289)	(509)	(595)

Note: Average across suppliers for 2007. Supplier-type is determined based on the mode of the governance type over all their transactions. Standard deviations in brackets.

These differences fit a dynamic interpretation in terms of a product lifecycle. When new technologies emerge and are embodied in new components, carmakers often have to produce them in-house as no market for them yet exists (Stigler, 1951). Once it becomes feasible to codify performance standards they can be outsourced to captive suppliers, but the buyers structure the collaboration to capture most of the surplus themselves. Captive suppliers initially receive training and knowledge transfers from their clients, but they invest strongly in R&D to build up their capabilities and graduate to a modular, more independent type of governance. That type of collaboration will generate them much higher profits. However, as the technology matures further, other suppliers also acquire the expertise and products become standardized, such that eventually market relationships governed by contracts becomes feasible and profit margins of suppliers collapse again.

The above dynamic saw codifiability increase before capabilities, but in some cases the order is reversed. The crucial expertise for new products originates in highly capable, specialized suppliers and the collaboration with carmakers takes the relational form. Suppliers spend a lot of resources on R&D, but are able to generate a decent profit margin. The close collaboration that the new technology still requires limits supplier's ability to sell their services to many clients. Only when it becomes possible to codify specifications in a more objective and easily transmittable fashion can they engage in more arm's length, modular collaborations, supply more clients, achieve greater bargaining power, and raise their profit margin. This process does not necessarily require as much R&D as creating a new technology, but still requires highly capable suppliers to standardize the technology. As this process continues, eventually the technology will lose its complexity and suppliers are increasingly chosen based on price and contracts used to govern relationships. In sum, governance becomes more market-like, which lowers supplier profits.

6. Conclusions

The main objective of our study was to illustrate that empirical work can and should go beyond firms' make-or-buy decisions. The framework we propose distinguishes five stylized governance types, which includes in-house production (hierarchy) as one extreme. By construction we do not observe in-house transactions in our dataset of sourcing contracts. Schmitt and Van Biesebroeck (2017) work with the same dataset and use the absolute frequency a transaction occurs relative to the overall size of the potential outsourcing market as a proxy for the (inverse of the) likelihood that a transaction is performed in-house by carmakers. While this is a very indirect proxy, their results show that the three explanatory variables have the expected predictions on the make-or-buy decisions.

The results in this paper show that those same characteristics of transactions or suppliers that predict whether an input is produced in-house or outsourced also predict how supplier relationships are organized. The proxy variables that are intuitively related to a particular way of organizing a sourcing relationship show systematic patterns with the explanatory variables of interest. The four governance types considered here are certainly not the only ones possible, but have showed how they follow naturally from the joint values of the three explanatory variables. The three explanatory variables we focused on were inspired by three highly developed economic literatures. Transaction cost economics emphasizes ex-post transaction costs due to holdup of specific assets, which we called lack of codifiability. The property rights theory emphasizes that allocating ownership rights can align the relative strength of investment incentives with the relative importance of either party's investments, which we measured by supplier capabilities. Both of these theories assume contracts to be incomplete, which we called complex transactions. The complexity might be a choice variable in some situations or it might evolve exogenously with technology.

In this framework, market governance will be chosen if complexity is low, and more complicated governance forms if complexity is high. Hierarchy is only chosen if both codifiability and supplier capabilities are low. If only one of these dimensions is problematic, outsourcing is still feasible, but the collaboration with suppliers will take a particular form. Suppliers will be captive (low supplier capability) or relational (low codifiability) to mimic the advantage of in-house production that one of the theories calls for, without losing the incentivizing advantage of outsourcing. When both dimensions are high, both TCE and PRT predict outsourcing, but the complexity of the transactions requires what we called modular governance, involving more design responsibility and bargaining power for suppliers than in market relationships that are governed by contracts.

The relationships between the four stylized governance types and the three explanatory variables of interest were largely consistent with the theoretical predictions. As one of the most downstream manufacturing industries, the automotive industry sources inputs in a wide variety of situations. The results suggest that carmakers tailor their way of sourcing in predictable way to the situations they encounter. Finally, the ordering of governance types in terms of the profit margins and R&D intensity for suppliers that use each type most frequently showed intuitive patterns. In particular, the patterns are consistent with R&D expenditures leading to higher capabilities and an evolution in governance. They are also consistent with technologies gradually becoming more standardized over their life-cycle and higher profitability for suppliers as they gain greater independence, until products become entirely standardized and profits are competed away. Such a dynamic interpretation of the evolution of sourcing is appealing, but not explicitly shown in our analysis. We leave a rigorous exploration of the dynamics for future work.

7. Appendix

Table A.1 Summary statistics

	No. of observations	Mean	Standard deviation
(a) Dependent variables			
Market	16,537	0.642	1.322
Modular	15,805	2.833	1.396
Relational	15,331	3.963	1.628
Captive	16,159	1.890	1.678
(b) Key explanatory variables			
Complexity	16,537	0.666	0.472
Capability	16,537	0.453	0.498
Codifiability	16,537	0.259	0.438
(c) Control variables			
Distance	16,047	0.966	2.152
Hofstede culture	16,537	0.402	0.490
Border effect	16,537	0.356	0.479
Contract length	14,343	81.694	19.486
Value Added	14,569	2.931	6.129

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