Governing supply relationships: Evidence from the automotive sector*

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Abstract

Many empirical studies analyze a firm's make-or-buy decision in an incomplete contracting framework. Transaction Cost Economics has highlighted the role of asset specificity, while the Property Rights Theory stresses the role of the contracting firms' relative marginal contribution to joint surplus creation. We show that proxies for both explanatory factors can also be used to distinguish between different ways of organizing an outsourcing relationship. Making the link with the literature on Global Value Chains, our framework predicts that the choice among five possible governance modes depends on three key variables: the complexity of the transaction, its codifiability, and the capability of the supplier. Our evidence using contract information from the automotive industry suggests that not all 'buy' relationships are alike and that the predictive value of our variables goes beyond the make-or-buy distinction.

Keywords: Outsourcing, global value chains, supply relationships
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1 Introduction

Several studies test one particular theory of the firm by explaining the make-or-buy decision based on a single crucial explanatory factor. There are, broadly speaking, two main issues with this approach. First, the variables used to predict the make-or-buy decision are often complementary, not just in their interpretation but also from a theoretical point of view. Second, such an approach overlooks the fact that many sourcing relationships cannot be easily classified as either "make" or "buy." In many situations, a particular theory will only be decisive where often implicit necessary conditions are satisfied.

There is, in contrast, an applied literature that treats such complementarities more explicitly and focuses on more complex forms of firm-to-firm relationships. Such relationships are sometimes called *networks* or hybrid forms of organization, and they have been frequently identified in case studies of industry. Can we explain observable features of *networks* using those same theories of the firm? That is, can we use the same explanatory variables that predict make-or-buy decisions to distinguish between different forms of buying?

The economics literature has developed several theories to explain firm boundaries. We will focus on two prominent theories, transaction costs (TCE) and property rights (PRT), and we will explicitly consider their implicit assumption of incomplete contracts. If activities can be redefined to make them describable by complete contracts they can more easily be outsourced (Maskin and Tirole, 1999; Aghion and Holden, 2011). If contracts are fundamentally incomplete, transaction costs and the risk of hold-up are likely to differ depending on whether an activity is organized within a firm or transacted over markets (Coase, 1937; Williamson, 1979). If non-contractible investments of two parties in a transaction have a very different impact on the joint surplus, it might be optimal to give one side more control and organize the transaction within one firm and put that side in charge (Grossman and Hart, 1986).

These theories predict why some activities are organized in-house while others are outsourced. Each has independently been tested and found some support in the data. For example, Levin and Tadelis (2010) find that city services that are subject to high transactions costs of contracting are less likely to be privatized. Monteverde and Teece (1982) find that parts requiring a lot of engineering effort in their design are more likely to be produced inhouse. Woodruff (2002) finds that Mexican shoe retailers are less likely to be vertically integrated with the shoe manufacturer in segments with high fashion turnover. Specific investments are high for these products, but they are borne by the retailer who should thus not be controlled by the manufacturer in an integrated firm. Lafontaine and Slade (2009) summarizes a broad range of the empirical literature.

To make progress integrating the distinct literatures, Gibbons (2005) describes several theories in a uniform framework and proposes a single unifying model that nests different explanations. We take a different approach and start from outsourcing relationships that are observed in our automotive data. We draw inspiration from two highly influential studies outside of economics to condense the information into distinct governance types. Powell (1990) has argued that a variety of sourcing configurations are possible in between the extreme cases of make or buy. The global value chains (GVC) theory of Gereffi, Humphrey, and Sturgeon (2005) uses three explanatory variables to generate a classification of four types of buying relationships.

To structure our empirical analysis, we provide an integrated framework to nest a topology of governance types into the three different strands in the economic theory of the firm. Rather than exhaustively partitioning all observed relationships in a few groups, we associate each governance type with a monotonic mapping to an observable continuous variable. For example, in a so-called captive relationship the buyer provides the supplier with technological support and guarantees it sufficient sales to operate without losses, but in return it demands exclusivity. The number of clients a supplier works for should vary inversely with the probability that the relationship is of a captive type. We further argue that the three component or buyer characteristics the GVC literature uses to predict governance types—complexity, codifiability, and capabilities—are closely related to the explanatory variables that the three economic theories of the firm have highlighted: ease of contracting, specific assets, and relative importance of marginal investments.

As mentioned, we test the predictive power of our framework using unique sourcing information that is usually highly confidential. Our data covers the automotive industry which is an interesting place to study theories of the firm as it touches on virtually all sub-sectors of manufacturing. Over the 1993–2012 period, we observe for nearly 10,000 buyer-component pairs which supplier holds the contract for a particular vehicle model. As we observe repeated contracting between buyers and suppliers and the type of components that different suppliers produce, we can construct the different proxies that characterize the nature of the relationship between the component divisions of suppliers (the supplier), e.g. Bosch-electronics or Faurecia-interiors, and the different automakers' design center (the buyer), e.g. Ford-Europe or Toyota-North America.

The remainder of the paper is organized as follows. Section 2 discusses the importance to make conditional statements when considering the predictions of the classic make-or-buy literature. Section 3 introduces the GVC theory as an organizing framework from which we obtain a set of conditional empirical relationships to estimate with our data. In the following Section 4 we give an overview of outsourcing relationships in the automotive industry, where we also introduce our data set. In Section 5 starts the core of our empirical analysis. Subsection 5.1 explains how we obtain proxies for different forms of outsourcing governance, and Subsection 5.2 explains the construction of our explanatory variables. The next two Subsections 5.3 and 5.4 show and discuss the results of our tests of the choice of governance, before concluding in Section 6. An appendix includes details about the construction of variables and alternative specifications.

2 Make-or-buy theories: the importance of conditional statements

Two of the most prominent theories in the "theory of the firm" literature are transaction cost economics (TCE) and the property rights theory (PRT). Models in the TCE literature focus on ex post transaction frictions and have as main predictor variable the costs of transacting. A well-studied example of costly transaction frictions is haggling over the division of ex post appropriable rents (Williamson, 1979). It is said to be endogenously determined by three idiosyncratic characteristics of transactions: the specificity of assets involved, the frequency of interactions, and the extent of uncertainty (Williamson, 1985). In this setup, a transaction is brought inside the firm when the costs of carrying it out on the market are sufficiently high.

In contrast, models in the PRT literature are largely game theoretical (Dessein, 2013). Transaction costs are not relevant for the distinction between in-house production and outsourcing since firms anticipate any cost disparities in their ex ante decisions. Crucial instead is the productivity of investments under either integration or separation of upstream and downstream assets, and the main predictor variable is marginal returns to investments (Grossman and Hart, 1986). Firms in a vertical bargaining game share unique relational rents which cannot be allocated by means of a formal contract (Klein, Crawford and Alchian, 1978). How much is there to be shared depends on how much firms invest in the relationship, and the amount of investments depends on the profitability of different ownership structures. In this setup, vertical integration is chosen if integration of assets makes investments more productive than an outsourcing relationship.

Despite somewhat different views on how the issue of rent-sharing is resolved by firms and how it influences their choice of governance, there have been attempts to try to reconciled different predictions of the theory of the firm (Gibbons, 2005). In order to analyze them under the same definition of a contract one would need to allow for, on one hand, some degree of bounded rationality as assumed in the PRT literature—where agents fully anticipate the costs and benefits of different states of the world—and, on the other hand, for the possibility of ex post haggling over the emergence of an unanticipated relational surplus—which would also influence ex-ante decisions as in the TCE literature (Hart and Moore, 1999).

Notice that both TCE and PRT theories assume the existence of non-contractible relational rents. However, whether a contract is more or less complete influences the amount of residual control rights available to the firm that owns the productive asset, which in turn creates the possibilities for bargaining and haggling over the division of relational rents seen in the above literatures (Aghion and Holden, 2011). Maskin and Tirole (1999) discuss describability in a similar way. The more potential states of the world that are covered by a contract (the more complete the contract), the higher its describability. Failure to assign contractual rights to potential states of the world raises the amount of residual rights in contracts with low describability. Thus, controlling for degree of contract completeness is important when looking at the other factors.

To understand the importance of conditioning on contract completeness, consider the role of residual rights in the predictions of TCE and PRT models. When a firm has a large amount of residual control rights over an asset that is critical in production, it generates specific rents that an external firm could try to appropriate. But the process of allocating these rents can create costs that are not easily transmitted through contracts, making them dependent of the form of governance. The TCE literature addresses this issue by modeling the bargaining frictions that generate transaction costs, but it takes the degree of contract completeness as exogenously given. Residual rights can also affect the value of property. The different surpluses that a specific asset can achieve often depend on who has the residual rights of control over it. Typically, the ability to extract rents from those residual rights creates different incentives to invest, making ownership dependent of the form of governance. The PRT literature addresses this issue by modeling returns to investments under different ownership structures, but it takes the amount of residual rights that ownership can provide as exogenously given.

Conditional on the amount of contractual and residual rights, the TCE and PRT theories offer each a conceptually different solution to the make-or-buy problem. Taken together however, these theories can provide a richer view on the problem that goes beyond the choice of governance along firm boundaries.

3 GVC as an organizing framework: obtaining testable predictions

The make-or-buy literatures discussed so far only model the choice of governance at the boundary of the firm. The choice is dichotomous, and so all transactions that are not carried out within firm boundaries are lumped together as a market governance type, as shown in the first column of Table 1.

Yet evidence suggests that there are more complex and variegated options for the governance of outsourcing relationships. A subsequent literature considers transactions in a hybrid type of governance often called *networks* (see the second column of table). In transactions of the network type, (i) contracts are incomplete, (ii) firms typically do under-invest, and (iii) there are high transaction costs, but outsourcing occurs nonetheless. Several attempts have been made to explain these apparent contradictions.

First, firms that choose to outsource when contracts are incomplete do so perhaps because their investments are asymmetric in the degree of specificity (Bensaou, 1999). While supplier investments may be quite specific (rendering a contract less complete and favoring integration), buyer investments may be much less specific, making outsourcing a viable form of governance. Second, even though outsourcing typically causes firms to under-invest by encouraging them to diversify investments towards alternative but less efficient ends, firms may be able to sustain a relationship over a longer period of time, providing them better incentives to focus investments towards the first-best, efficient end (Baker, Gibbons and Murphy, 2002). And third, while outsourcing may be plagued by frictions in contracting, it may be a better solution for firms who seek to exploit firm-specific resources or unique capabilities. Powell (1990) has pointed out that one of the principal aspects of those network forms of governance in the second column is the overall high degree of inter-connectedness between the outsourcing firms.

Table 1: Literature on governance choice

Make-or-buy literature	Networks literature	GVC literature
Market	Market	MARKET
	Networks, hybrid type	MODULAR
		RELATIONAL
		CAPTIVE
Hierarchy	Hierarchy	HIERARCHY

Source: adapted from Sturgeon (2008: p. 16)

A more recent strand of literature is largely evidence-driven and makes several important findings regarding the governance of outsourcing relationships. Gereffi (1999) finds that lead firms play an important role in the governance of the apparel supply chain. He describes producer-driven supply chains characterized by large manufacturers that dominate upstream suppliers, and buyer-driven supply chains characterized by large retailers dictating norms and requirements to their network of captive suppliers. The study by Sturgeon (2002) finds that in electronics contract manufacturing, turn-key suppliers play an important role in the production of customized goods with a multi-use interface, which allows for the use of larger-scale generic manufacturing capacity that limits transaction-specific investments and shifts some bargaining power to the supplier, in what he calls a modular type of governance. Asanuma (1989) studies outsourcing relationships in the Japanese automotive industry, and finds that suppliers accumulate unique relationship-specific skills through learning and technological investments that are ultimately borne by both buyers and suppliers, creating a high degree of relational inter-dependency.

In the theory of value chain governance of Gereffi, Humphrey and Sturgeon (2005), some of the findings from the above case studies are incorporated into a framework that breaks governance down to five ideal types. Their typology replaces the intermediate network type with three distinct categories of governance, namely modular, relational and captive (see the third column of Table 1). Modular governance is characterized by turn-key suppliers of customized products with a multi-use interface. Relational governance is said to occur in transactions that involve a number of mutual dependencies, often sustained by close ties and trust. And captive governance is characterized by the dominating role of the lead firm. The theory also includes an arm's length, market governance type, and a hierarchy type for transactions within firms.

To predict the choice of GVC governance, three explanatory variables are introduced by Gereffi et al. (2005):

1. the *complexity* of transactions,
2. the degree of *codifiability* of transactions,
3. and the *capability* of the supply base.

Transactions that exhibit rather low degrees of complexity will take place on standard, spot markets. More *complex* transactions will instead be carried out either within an integrated firm (as in the theory of the firm), or in one of the three distinct categories of outsourcing relationships (replacing networks in the last column of Table 1): that is in either modular, relational or captive relationships. Next, transactions that are difficult to *codify* will be better supported by the relational type of governance, when not by hierarchical governance. Finally, for transactions where suppliers lack the necessary *capabilities*, a captive relationship will be implemented. When the entire supply base does not have the needed capabilities, the buyer will choose to organize the transaction in-house. To obtain the prediction of which exact governance form is chosen, the variables are combined in different configurations of high or low complexity, high or low codifiability, and high or low supplier capability.

We use the GVC theory as an organizing framework to analyze relationship governance in view of the PRT and TCE literatures. We discuss how the predictions regarding complexity, codifiability and supplier capability can be interpreted in terms of conditional statements from the theory of the firm. Complex transactions can lead to difficulties in the design of an appropriate outsourcing contract. Bajari and Tadelis (2001) show in their model how contracts can be endogenously designed as a response to project complexity. Thus, in order to control for the degree of contract completeness it is important to condition on complexity. Furthermore, a transaction that is hard to codify does not clearly specify how residual rights are allocated, which results in potential ex post haggling over the division of relationship surplus, and higher transaction costs. This tells that in order to control for amount of transaction costs it is important to condition on codifiability. Moreover, a supplier that is more productive than the buyer is also relatively more capable in making investments in relationship-specific assets. This tells us that in order to control for the relative productivity of firms it is important to condition on supplier capability.[1]

Table 2 combines four conditional statements of the theory of the firm with four GVC variables. As shown in the table, given high complexity, firms will choose either modular, relational, captive or hierarchical governance. To predict which of the four governance types is chosen, we first consider a classic prediction from the PRT literature. When the supplier is relatively more pro-

[1]Supplier capability is meant in overall relative terms, *i.e.* relative to the buyer and to the other potential outcomes of the governance choice process.

ductive, the firm will choose to outsource despite this meaning that a potentially high amount of residual rights is transferred to the supplier. Hence, suppliers with relatively high marginal returns enter either modular or relational relationships. Notice that the PRT literature does not make the distinction between the captive and hierarchy types, as in both cases the less productive supplier loses ownership of the downstream asset in the *ex ante* deal. Now conditioning on a statement from the TCE literature, when transaction costs are low as in modular and captive relationships, outsourcing is a viable alternative to in-house production. Notice here again that the TCE literature does not make the distinction between relational and hierarchy, as in both cases there is too much potential for *ex post* haggling over the division of relational rents. Finally, combing all variables we obtain that hierarchy will be chosen only when the marginal returns of the potential supplier are low and transaction costs are expected to be high.

Table 2: The choice of GVC governance when contracts are incomplete and transactions are complex

Difficulty to codify transactions			*TCE: Transaction costs*	
			High	Low
Capability of the supply base	*PRT: Supplier marginal returns*	Low	HIERARCHY	CAPTIVE
		High	RELATIONAL	MODULAR

While Table 2 derived four conditional statements assuming that contracts are incomplete and transactions are complex, relaxing this assumption could change the predictions. High transaction costs predict in-house production in the TCE literature, but this invariably depends on the specificity of the assets involved. Controlling for the degree of contract completeness accounts for this kind of simultaneity. For instance, when assets are not specific but generic, excess residual rights can be traded away in the market, in which case contracts become sufficiently complete for transaction costs to be written down explicitly and transmitted through prices. Similarly, high marginal returns predict vertical integration in the PRT literature, but in the absence of residual rights of ownership, productive investments in upstream or downstream assets do not create the types of unique benefits that outweigh the costs of using the market.[2] Hence, when contracts involve investments that are generally quite generic and also involve little uncertainty, trade on markets is always preferred over integration.

To illustrate how conditioning on different levels of supplier marginal returns and transaction costs can change the choice from make to buy, consider the following Table 3. Cases (1) to (4) of Table 3 are instances in which specific investments and uncertainty make contracting difficult, and subtle variations in the characteristics of transactions lead to different choices of outsourcing governance.[3] Even when investments are specific and highly productive, significantly low transaction costs imply that the likelihood of haggling is very low and outsourcing is viable. This is common of transactions where the use of more direct control and power prevents shirking and costly re-contracting. A shift from high to low transaction costs induces this change from make (1) to buy (2). On the other hand, when marginal returns are very low and the firm cannot make any productive use of the specific assets required, it is better off relying on an outside supplier, even if high transaction costs mean engaging in costly interactions. A shift from make (1) to buy (3) represents this case. Finally, case (4) corresponds to the situation in which both marginal returns and transaction costs are simultaneously low, favoring outsourcing. Similarly as in the make-or-buy cases illustrated above, a shift from buy (2) to buy (4) involves reorganizing the outsourcing relationship to allow the supplier more autonomy in making relationship-specific investments (since they are more productive), and a shift from buy (3) to buy (4) means less dependence on costly interactions with the supplier. Although comparable to a more arm's length case, case (4) is still unique in that it involves a significant amount of residual rights allocated to the supplier due to incomplete contracting. Because these rights are unique (they are attached to specific assets), it gives the supplier room for differentiation on the market.

[2] In particular, for sufficiently complete contracts, we say that suppliers are equally capable of carrying out the investments, and market transactions are preferred because they spread the risks of random shocks to productivity.

[3] Because we are interested in variations in the governance of outsourcing relationships, *low* is assumed to be sufficiently low to induce *buy* even when the other variables are *high*. Combinations of *high* and *low* that cause *make* are theoretically possible and would predict alternative forms of in-house governance, but their analysis is not intended in this paper.

Table 3: Conditional statements from theory and the choice to outsource

PRT: Supplier marginal returns	*TCE: Transaction costs*	Make-or-buy	
Low	**High**	Make	(1)
	Low	Buy	(2)
High	**High**	Buy	(3)
	Low	Buy	(4)

4 Sourcing relationships in the automotive industry and overview of the data

The automotive industry is particularly well suited for the study of governance. One of the earliest empirical tests of the TCE theory is Monteverde and Teece (1982), with data on automotive parts manufacturing. They measure the effort that goes into engineering an automotive component, and find that it strongly predicts in-house production. In this classic study of the make-or-buy problem, the variable of interest indicates whether a large share of a component's production takes place in-house, while all external supply relationships are aggregated as one form of outsourcing governance.

In contrast, more recent studies of the industry focus on the rich heterogeneity in supply chain relationships. Humphrey (2004) studies the formation of global automotive supply networks, and Sturgeon, Van Biesebroeck and Gereffi (2008) analyze recent trends in the industry, emphasizing the importance of governance in value chain linkages, with an application of the GVC framework. Different types of relationship governance are also found in several case studies of the industry. Asanuma (1989) provides an early account of relational governance in the Japanese automotive industry, and Kotabe, Parente and Murray (2007) study modular production strategies in the Brazilian automotive industry. Helper (1991) shows how relationships in the American automotive industry have evolved from the traditional arm's length market type, and Klein (2007) investigates the failed attempt of General Motors to hold Fisher Body a captive supplier. The rich diversity in the technologies supplied also contributes to this heterogeneity. The automotive industry is the most downstream industry in the study of the upstreamness of U.S. manufacturing by Antras, Chor, Fally and Hillberry (2012).

To study relationship governance we use transaction-level data on first and lower-tier supply contracts. The data comes from *SupplierBusiness*, a consultant to the industry, and covers transactions from 1993 through 2012. It includes all major carmakers and global first-tier suppliers. In addition, the data includes over a thousand small and medium supplier firms located in Europe and North America. Table 4 summarizes some of the key characteristics of our data. We observe 64 unique buyers "b", defined as an original equipment manufacturer (OEM) in one of the two regions, Europe or North America. We also observe 213 unique products "p", defined using the detailed component categories provided by *SupplierBusiness*, 350 different car models "m" of different OEMs, and 2,205 unique suppliers "s", defined as the product division of a supplier firm in one of the two major geographic regions (more details on the component categories are given in the Appendix).

Table 4: Data on automotive supply relationships

		By global supplier			By global OEM		
Number of	Total	Mean	St. Dev.	Skew.	Mean	St. Dev.	Skew.
Buyers b	64	38.1	18.6	-0.551	1.42	0.49	0.315
Products p	213	38.0	34.2	1.09	193	27.3	-2.43
Models m	350	144	97.4	0.053	12.0	5.88	0.224
Suppliers s	2,205	3.80	1.38	-0.758	378	144	-0.245
Bundles bs [a]	12,908	84.0	63.6	0.638	427	195	0.229
Relations bsp [b]	25,563	269	285	1.31	906	455	0.283
Transactions $bspm$ [c]	43,575	539	593	1.31	1,722	1,013	0.268

Note: The full sample contains 57,354 observations. [a]Bundle is defined as the aggregate of contracts between a buyer and a supplier. [b]A relation is a series of transactions between a buyer and a supplier for a specific product. [c]A transaction is a unique combination of a buyer, a supplier, a product and a car model.

Table 4 also contains our definitions of bundles, relations and transactions. We define bundle as a the aggregate of contracts between a buyer and a supplier, that includes contracts for different car parts and to different car models.[4]

[4]For the purposes of our analysis, we do not use the definition of a module in the technological sense of the word, as we wish to capture the challenges that modular production

A relation is defined as a series of transactions between a buyer and a supplier for a specific product. And finally, a transaction is defined as a unique combination of a buyer, a supplier, a product and the car model that it is supplied to. The following scheme shows how these definitions are made in the data:

- Bundle: a unique combination of a buyer b & a supplier s;
- Relation: a unique combination of a buyer b & a supplier s & a product p;
- Transaction: a unique combination of a buyer b & a supplier s & a product p & a car model m.

Because the data set has a time dimension, even our most detailed definition of a unique transaction will contain a few repeated transactions over time. On average, about one in every three transactions reoccurs in the data set, which has a total of 57,354 observations.

In the subsequent columns of Table 4, the data is given by global suppliers and global OEMs. Notice that suppliers are more representative of the characteristics of transactions. In the second row of the table, for instance, the average number of products supplied is 38, with a high standard deviation and a positive skewness across suppliers. It means that the majority of suppliers supply less than 17.8% of the products observed. In contrast, the vast majority of carmakers use more than 90.6% of all products observed. Since the characteristics of products—as well as modules, relations and the other contract variables—are crucial in the choice of relationship governance, the variation in supplier characteristics is also key for the identification of governance types. We use this feature of the industry to model heterogeneity in governance types below in Section 4.1.

To the data on contracts we add firm-level data collected from Amadeus, a database with broad European coverage of firms in the automotive industry, described quite extensively in Schmitt and Van Biesebroeck (2013). This additional information is used to generate a set of relevant control variables, below in Section 5.2.

represents in the contracting dimension.

5 Estimating the choice of relationship governance

5.1 Obtaining proxies for the different types of GVC governance

To test the make-or-buy choice it is fairly easy to obtain a variable that indicates whether a transaction takes place inside a firm or outside on markets. This has to do with the fact that firm borders are mostly easy to observe. To estimate outsourcing governance, however, the task of obtaining unambiguous indicator variables or proxies is much more difficult. Since the different forms of outsourcing governance all take place between outsourcing firms, we need to look for more nuanced characteristics of the transactions.

Berry (1994) and Verboven (1996) show how the market share of a product can inform us about the choices of consumers. While they models more specifically consumer demand, the general model can as well be interpreted in terms of an outsourcing firm's choice of a supplier (or of a type of supply relationship). We use the GVC literature to obtain the key characteristics of governance which are most relevant to identify each different governance type, and we use as proxy variable different measures of market share. A relationship j's contribution to a market share is calculated using information about the monthly production volumes of the car models covered by relationship j. We only observe the projected quantities, but this should be tolerable since they are projected approximately at the time when the supply contract is signed. Thus, a market share σ_j is constructed as follows:

$$\sigma_j = \frac{\sum_{n \in N_j} q_n}{\sum_{n \in N} q_n + Q_0},$$

where q_n is the (projected) production of an individual outsourcing contract, and N_j is the set of outsourcing contracts within a definition of relationship. As seen in the previous section, we use several definitions for j: the set of contracts that a specific buyer b holds, or analogously a supplier s, or the bundle bs, etc. $Q_0 = M - Q_N$ is a crude measure of the outside good obtained by subtracting the observed production $Q_N = \sum_{n \in N} q_n$ implied by all of the outsourcing contracts in our data set from an estimate M of the industry's total production volume. For M we use global production volumes for the years 1997-2012, obtained from the *International Organization of Motor Vehicle Manufacturers* (OICA), a think tank for 35 national trade associations in the automotive industry. We harmonize these quantities by region (Europe or North America) and time (in months).

As discussed in the previous section, automotive suppliers carry the crucial characteristics of transactions that we wish to use for identification of the different types of outsourcing governance. (Since suppliers are often organized in several product divisions, each maintaining a potentially different type of client relationship, we use the definition of supplier developed in the previous section, i.e. a supplier is a regional product division of the firm.) When suppliers face strong competition from a large number of other suppliers in the market for a rather common product, we identify a transaction that is more market-like. It implies a low supplier market share σ_s and a relative large product market size σ_p. When suppliers are able to capture a large bundle of contracts (implying high σ_s) for the delivery of a turnkey module that can be redeployed over different customers (implying low σ_{bs}), we identify a transaction that is more modular-like. Yet when suppliers are successful in capturing many contracts because they reoccur (high σ_s) in rather unique relationships (low σ_{bsp}), we identify a transaction that is more of the relational type. Finally, when suppliers with little market influence (low σ_s) supply to buyers that exhibit relatively high market power (high σ_b), we identify a transaction that is more of the captive type. Below in Table 5 we summarize our method to identify governance types, showing the dependent variable *Depvar* generated as the logarithm of relative market shares.

We can also view *Depvar* as capturing the observed market position of suppliers given the relevant market for either market, modular, relational, or captive transactions. High competition for rents with other suppliers, and an unbalanced power relation between the buyer and the supplier, lead to a weak market position for suppliers in market and captive transactions, respectively. Controlling for the size of the product market and the size of the buyer are important to distinguish each case. High market differentiation from other

Table 5: Identifying governance types

Governance type	Effect	Share of	Relative to share of	*Depvar*
MARKET	Low	Supplier	Product	$-\ln(\sigma_s/\sigma_p)$
MODULAR	High	Supplier	Bundle [a]	$+\ln(\sigma_s/\sigma_{bs})$
RELATIONAL	High	Supplier	Relation [a]	$+\ln(\sigma_s/\sigma_{bsp})$
CAPTIVE	Low	Supplier	Buyer	$-\ln(\sigma_s/\sigma_b)$
HIERARCHY	Low	Transaction [a]	Outside good	$-\ln(\sigma_{bspm}/\sigma_0)$

Note: [a]See definition in Table 5, footnote.

suppliers, and a strong position in the division of rents between the buyer and the supplier, lead to relational and modular transactions, respectively. Controlling for the uniqueness of the relationship and of the module in question are important to distinguish each case. For instance, a borderline large supplier might actually represent the market type if the product it sells takes up a very large chunk of the overall product market. It might instead represent the captive type, if its client is so large that there are few alternative outlets on the market, making market rivalry between suppliers less indicative of its low market share. Yet if it concerns a transaction that is very unique, then a borderline large supplier has a high *Depvar* and it represents continuing success in the relational type, and if it involves a redeployable bundle of contracts (including different products to different uses), then a high *Depvar* means that it captures many contracts of the modular type. Notice that our definitions of *Depvar* are intentionally more general than detailed, allowing for potentially overlapping governance types. Although this comes at the expense of identifying somewhat weaker average effects, it helps us avoid making more restrictive assumptions on the types.

To estimate hierarchy governance, we look at the information contained in each transaction. Since this case corresponds to the choice of governance at the boundary of the firm, the characteristics of both buyers and suppliers are important, as well as the characteristics of the product being outsourced and its intended use. A transaction that is underrepresented in the supply market (low σ_{bspm}) is probably more often carried out in-house as the hierarchy type. Also, transactions that are not observed at all on the market (high σ_0) are probably carried out within firm boundaries.

5.2 Construction of the GVC variables and other control variables

Our main explanatory variables are complexity, codifiability and supplier capability. We construct them using detailed information on transactions (from *SupplierBusiness*), and firms (from *Amadeus*). To construct the complexity and codifiability measures, we use three levels of component descriptions from our transactions data. The variables are based on a conservative binary classification: products involve either complex or noncomplex transactions, and either codifiable or non-codifiable transactions (the full list of product categories and classifications is given in the Appendix, where we also show a more flexible specification). Complex are mainly electronics and electrical components and a few other components that require a good deal of engineering effort in design and production. These include components in the powertrain and in the chassis areas of a car. The mean of this variable is 0.581. Codifiable are components that go primarily in the interior and exterior areas of a car, save airbags, brakes and a few others. Some sub-components that appear across all areas of the car are also highly codifiable, as for example fasteners and fixings, and switches and cables. The mean of this variable is 0.307, and the sample correlation between the complexity and codifiability variables is strongly negative at -0.728.

Our variable of supplier capability is given as the size of the supplier relative to its age. A literature on firm capability and learning finds that firms compete on the basis of internal resources that take time to develop (Penrose, 1959). Moreover, recent research by Haltiwanger, Jarmin and Miranda (2013) shows that it is important to control for firm age when looking at the effects of firm growth. The variable is constructed using company data on suppliers, and is defined as the supplier's turnover (operating revenues in 2007) divided by the age of its branch or headquarters (date of incorporation). For ease of interpretation we dichotomize it at the mean of the effect of age on turnover. The final variable takes on the value 1 if the supplier is capable, and 0 if the supplier is not. Its mean is 0.453, and the sample correlation between complexity and capability is 0.0211, and between codifiability and capability is -0.0253.

In addition to the three variables from the GVC theory, we also collected some important control variables from the *Amadeus* dataset (for the year 2007). Geographical proximity is known to play an important part in both the decision to outsource and the choice of outsourcing relationship (Schmitt and Van Biesebroeck, 2013). For instance, the decision to vertically integrate production sites is found to depend on proximity to input suppliers (Joskow, 1985). We therefore include the distance from the supplier plant to the client, in kilometers. Next, cultural, historic, institutional and family ties are expected to play a role in the organization of outsourcing relationships. We include a variable of cultural distance using the survey data of Hostede (1980), measured at the country level and calculated as the Mahalanobis distance over four dimensions: individualism, power distance, uncertainty avoidance, and masculinity. In addition, we include a dummy variable for the effect of country borders, which is an important variable in the analysis of foreign direct investment.

Contract length is proxied by the number of months between the start and end of production of a car model. Longer contracts can be seen as a compensation for uncertainty in a buyer-supplier relation (Joskow, 1985). Since uncertainty plays a key role in transactions (Williamson, 1985), it will be important to control for its influence. We also add a proxy for value added, defined as operating revenues over total assets. The following Table 6 shows the pairwise correlations of our explanatory variables.

Table 6: Sample correlations of the explanatory variables

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Complexity	(1)	1.0000							
Codifiability	(2)	-0.7280	1.0000						
Capability	(3)	0.0211	-0.0253	1.0000					
Km Distance	(4)	-0.1217	0.0437	-0.2027	1.0000				
Hofstede Culture	(5)	0.0263	0.0050	0.0503	0.1432	1.0000			
Border Effect	(6)	-0.0876	0.0090	-0.1983	0.4361	-0.2415	1.0000		
Months Production	(7)	0.0222	-0.0046	-0.0365	-0.2683	-0.0713	-0.0219	1.0000	
Proxy Value Added	(8)	0.1404	-0.1180	-0.3175	-0.0906	-0.0292	-0.0417	0.0444	1.0000

Note: The sample has 12,343 observations.

5.3 Results of simple regressions: testing each GVC type separately

In this section we regress our variables of complexity, codifiability and supplier capability (constructed in Section 5.2) on different proxies of governance (constructed in Section 5.1). Here the approach is to run a separate regression for each type of GVC governance, to find which variables can best distinguish one type from the others.

As discussed above, the GVC theory uses different configurations of high and low for complexity, codifiability and capability to predict the choice of value chain governance, shown below in Table 7. A market form of governance is predicted when complexity is low, and notice that low complexity is sufficient to predict market since complexity is higher in the other types to the right (first row of the table). Low codifiability predicts relational governance and also hierarchy, but since hierarchy is the in-house form of governance, it is characterized as having a very small representation (if at all) on the outsourcing market. Thus we expect to see low codifiability as a good predictor of relational governance. Finally, low capability predicts captive governance and also hierarchy, but here again we expect the effect on hierarchy to be comparably very weak. Thus low supplier capability should be a good predictor of captive governance. Modular and hierarchy are harder to test, because there are no direct predictions using only one of the explanatory variables. Nonetheless, when codifiability and capability are simultaneously high, we should expect to see modular as the chosen form of governance. Similarly for hierarchy, it can be predicted by codifiability and capability being simultaneously low.

Table 7: Predictions from the GVC theory

	MARKET (1)	RELATIONAL (2)	CAPTIVE (3)	MODULAR (4)	HIERARCHY (5)
Complexity	Low	**High**	**High**	**High**	**High**
Codifiability	**High**	Low	**High**	**High**	Low
Capability	**High**	**High**	Low	**High**	Low

Source: Adapted from Gereffi, Humphrey and Sturgeon (2005: p.87).

Tables 8-9 show the basic results of our estimation of GVC governance, where we use simple least squares regressions on the log of market shares. So for the market type, the simplest regression takes the following form:

$$-\ln(\sigma_s/\sigma_p) = \beta_0 + \beta_1 \times D_n^{complex} + \varepsilon_n,$$

where $D_n^{complex}$ is a dummy variable indicating high complexity in observation n, and ε_n is the least squares residual. Note that estimation of the remaining types is done in the same way. In the tables, we show three different regressions for each of the five different types of governance. The first two columns of each type report the simplest specifications of GVC variables needed to identify a governance type. The first column always shows the effect of the single GVC variable that should sufficiently predict a type. The second column adds all three GVC variables, and the sample is kept the same in the first two columns. In the third column of each type we add a set of relevant control variables, which impacts the estimation sample somewhat as these variables come from another data source.

We obtain results that largely support the GVC theory, that is, the three GVC variables are found to be in general good predictors of our proxies of the governance types. In column (1) of Table 8, low complexity has an especially strong effect in predicting a supplier with a small share in a product market (recall the definition of dependent variables in Table 5). It decreases the share of the supplier relative to the share of the product market, by -0.602%, and this negative effect is also found in column (2) where all three variables are included. In addition, the partial effect of codifiability is positive for the market type, which is very plausible given that market products tend to be more standardized than products in the other types of contracts. In column (4), low codifiability strongly predicts relational governance, even when we control for the effect of the other variables. It tells that when codifiability is low, a supplier has a high market share compared to the share of the particular buyer-supplier-component relationship that the supplier belongs to. The partial effects of complexity and supplier capability are strong and positive in column (5). In column (7), low supplier capability predicts a small supplier market share relative to the market share of his buyer, in a captive type of relationship. This holds even when controlling for the other GVC variables in column (8), where the negative effect of complexity means that captive relationships are

Table 8: The effect of complexity, codifiability and supplier capability on proxies of governance, including controls

	MARKET			RELATIONAL			CAPTIVE		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Complexity	-0.602***	-0.481***	-0.540***		0.347***	0.415***		-0.379***	-0.515***
	(0.0229)	(0.0351)	(0.0371)		(0.0441)	(0.0467)		(0.0452)	(0.0483)
Codifiability		0.171***	0.0643	-0.506***	-0.219***	-0.120**		0.0298	-0.102**
		(0.0378)	(0.0395)	(0.0310)	(0.0475)	(0.0498)		(0.0487)	(0.0515)
Capability		0.00160	-0.138***		0.108***	0.399***	-0.0740***	-0.0656**	-0.295***
		(0.0216)	(0.0244)		(0.0272)	(0.0307)	(0.0280)	(0.0279)	(0.0317)
Km Distance			0.0763***			-0.00323			-0.0215**
			(0.00744)			(0.00938)			(0.00969)
Hofstede Distance			-0.112***			-0.259***			0.385***
			(0.0235)			(0.0296)			(0.0306)
Border Effect			0.0653**			0.00305			-0.0331
			(0.0273)			(0.0344)			(0.0356)
Months Production			-0.00690***			0.0129***			-0.00313***
			(0.000596)			(0.000750)			(0.000776)
Proxy Value Added			-0.0445***			0.0475***			-0.0358***
			(0.00195)			(0.00245)			(0.00254)
Constant	1.027***	0.901***	1.701***	4.071***	3.716***	2.409***	1.933***	2.175***	2.631***
	(0.0187)	(0.0348)	(0.0649)	(0.0158)	(0.0437)	(0.0817)	(0.0188)	(0.0447)	(0.0845)
Observations	14,061	14,061	12,060	14,061	14,061	12,060	14,061	14,061	12,060
R-squared	0.047	0.048	0.133	0.019	0.024	0.097	0.000	0.013	0.054

Note: Simple least squares regressions. The dependent variables for the different governance types are defined in Table 5. Standard errors in parentheses; * p<.1; ** p<.05; *** p<.01

Table 9: Continued from Table 8

	MODULAR			HIERARCHY		
	(10)	(11)	(12)	(13)	(14)	(15)
Codifiable and capable	0.0391					
	(0.0370)					
Codifiable or capable				-0.0957***		
				(0.0214)		
Complexity		0.0819**	0.127***		0.0606*	-0.00400
		(0.0378)	(0.0398)		(0.0342)	(0.0364)
Codifiability		-0.0272	0.00802		-0.156***	-0.192***
		(0.0407)	(0.0424)		(0.0368)	(0.0388)
Capability		0.0169	0.163***		-0.0223	0.112***
		(0.0233)	(0.0261)		(0.0211)	(0.0239)
Km Distance			-0.0104			-0.00605
			(0.00798)			(0.00730)
Hofstede Distance			-0.579***			0.00699
			(0.0252)			(0.0230)
Border Effect			0.124***			0.112***
			(0.0293)			(0.0268)
Months Production			0.00713***			0.0159***
			(0.000639)			(0.000584)
Proxy Value Added			0.0175***			0.0173***
			(0.00209)			(0.00191)
Constant	2.788***	2.737***	2.217***	11.07***	11.03***	9.636***
	(0.0123)	(0.0374)	(0.0696)	(0.0166)	(0.0338)	(0.0636)
Observations	14,061	14,061	12,060	14,061	14,061	12,060
R-squared	0.000	0.001	0.073	0.001	0.005	0.078

Note: Simple least squares regressions. The dependent variables for the different governance types are defined in Table 5. Standard errors in parentheses; * p<.1; ** p<.05; *** p<.01

less complex than the average of the other outsourcing types.

Modular governance can be tested with a variable that indicates that both codifiability and capability are high. This is the case in only 11.2% of the observations and even though the effect is positive, in column (10) of Table 9, it can not strongly predict modular governance, also not when all three GVC variables are added in column (11). Lastly, transactions that are weakly represented on the outsourcing market relative to the alternative of in-house production are used as a proxy for the hierarchy form of governance. We construct a variable that is 1 if either codifiability or capability are high, and 0 if they are both low. This variable can strongly predict the hierarchy type in column (13). The next column (14) adds all three GVC variables, where the prediction holds that complexity should be high, codifiability low and capability low in hierarchy.

In columns (3), (6), (9), (12) and (15), we add control variables for alternative explanations of governance choice that are used in the literature. In these estimations, the effects of the GVC variables remain largely the same and in line with predictions, with the exception of capability in column (15). The effects of some of the control variables are also meaningful. The distance effect is in most cases negative, especially for captive since these relationships often see the captive suppliers co-located with their clients. But the effect of distance is positive for market relationships, which is to be expected as market products are often traded internationally and shipped from greater distances. The effect of cultural distance is negative in most cases, particularly in relationships where close collaboration is important, such as in relational governance. But it is positive for captive relationships, hinting at the need to maintain stronger control over the supplier. From the estimates for the variable Months of Production we see that relational and modular governance are correlated with the longest lasting production lines, while market relationships appear to be on average much shorter. The proxy of value added exhibits the same pattern.

5.4 Additional pairwise comparisons: testing one GVC type against another

In Table 10 we compare the choice of governance pairwise, that is, we estimate the effects of the variables specified in the previous table but look instead at the choice between two different governance types. Here we compare only between the network types of governance, but we also include hierarchy for completeness. In the top part of the table, the approach is to regress on the log difference of the market shares of two different governance types Y and X, using again simple least squares. So for the first regression of the relational type versus the modular type, we estimate:

$$\ln(\sigma_s/\sigma_{bsp}) - \ln(\sigma_s/\sigma_{bs}) = \beta_0 + \beta_1 \times D_n^{complex} + ... + \varepsilon_n.$$

In the bottom part of the table, the approach is to regress on a dichotomous variable that takes on the value 1 if the transaction is of a certain type of governance Y and not of another type X, and 0 otherwise. For this we categorize the different governance types using the observations that fall above the median of the distribution of our governance proxies, and we estimate this using probit regressions. That is, for the comparison of the relational type versus the modular type in the first regression:

$$\Pr\left[\ln(\sigma_s/\sigma_{bsp}) > p^{50\%}\ \&\ \ln(\sigma_s/\sigma_{bs}) < p^{50\%}\right] = \Phi\left(\beta_0 + \beta_1 \times D_n^{complex} + ...\right),$$

where Φ is the cumulative normal distribution and $p^{50\%}$ is the 50% percentile (median) of the sample distribution of each *Depvar*.

In columns (1)-(6), the interpretation of coefficients is as odds ratio. In the first column, low codifiability increases the odds of relational governance relative to modular by 0.128%, or conversely, high codifiability makes modular 3.47% more likely than relational. In terms of market shares, it implies that low codifiability increases the share of a buyer-supplier-component relation relative to the share of a bundle of buyer-supplier transactions by 0.288%. We highlight the estimates that should come out with a clear change in sign according to the predictions of Table 7. A clear distinction between relational and modular governance is that codifiability is expected to be lower in relational governance. Similarly, a key difference between captive and modular is that in captive relationships, the supplier is less capable. We first compare relational, captive and hierarchy against modular in columns (1)-(3), where the signs of the GVC variables are all in line with prediction. Next in columns (4)-(5) we compare relational and captive to hierarchy. When a supplier becomes more capable, our test in column (4) suggests that firms would switch from vertical integration to relational outsourcing, and when the transaction becomes more codifiable, they would switch from vertical integration to a captive outsourcing relationship according to column (5). The last column (6) compares relational to captive, where the expected changes in sign do occur, but interestingly, there is a strong effect for complexity.

Interesting are also the effects of some of the control variables that are included throughout in the estimations. Hierarchy appears to exhibit the longest contracts in terms of the variable Months of Production, followed by relational. The type of relationship that adds most value appears to be relational outsourcing, and the least value-adding is a captive relationship. The importance of distance, border and culture is much more ambiguous in these pairwise

Table 10: Pairwise comparisons of governance types, two estimation methods

Y :	RELATION	CAPTIVE	HIERARCH	RELATION	CAPTIVE	RELATION
X :	MODULAR	MODULAR	MODULAR	HIERARCH	HIERARCH	CAPTIVE
$\ln(Y) - \ln(X)$	(1)	(2)	(3)	(4)	(5)	(6)
Complexity	0.288***	-0.642***	-0.131***	0.419***	-0.511***	0.930***
	(0.0302)	(0.0833)	(0.0389)	(0.0400)	(0.0682)	(0.0889)
Codifiability	-0.128***	-0.110	-0.200***	0.0722*	0.0904	-0.0182
	(0.0321)	(0.0888)	(0.0415)	(0.0426)	(0.0728)	(0.0948)
Capability	0.236***	-0.458***	-0.0510**	0.287***	-0.406***	0.693***
	(0.0198)	(0.0547)	(0.0255)	(0.0262)	(0.0448)	(0.0584)
Km Distance	0.00720	-0.0111	0.00438	0.00282	-0.0155	0.0183
	(0.00605)	(0.0167)	(0.00780)	(0.00802)	(0.0137)	(0.0178)
Hofstede Culture	0.321***	0.964***	0.586***	-0.266***	0.378***	-0.644***
	(0.0191)	(0.0527)	(0.0246)	(0.0253)	(0.0432)	(0.0563)
Border Effect	-0.120***	-0.157**	-0.0112	-0.109***	-0.145***	0.0361
	(0.0222)	(0.0614)	(0.0287)	(0.0295)	(0.0503)	(0.0655)
Months Production	0.00576***	-0.0103***	0.00874***	-0.00298***	-0.0190***	0.0160***
	(0.000484)	(0.00134)	(0.000624)	(0.000642)	(0.00110)	(0.00143)
Proxy Value Added	0.0300***	-0.0533***	-0.000172	0.0302***	-0.0531***	0.0833***
	(0.00158)	(0.00437)	(0.00204)	(0.00210)	(0.00358)	(0.00467)
Constant	0.192***	0.414***	7.419***	-7.227***	-7.005***	-0.222
	(0.0527)	(0.146)	(0.0680)	(0.0699)	(0.119)	(0.155)
R-squared	0.108	0.062	0.060	0.054	0.072	0.079

Y :	RELATION	CAPTIVE	HIERARCH	RELATION	CAPTIVE	RELATION
X :	MODULAR	MODULAR	MODULAR	HIERARCH	HIERARCH	CAPTIVE
$Y = 1 \,\&\, X = 0$	(7)	(8)	(9)	(10)	(11)	(12)
Complexity	0.242***	-0.223***	-0.144**	0.316***	-0.27***	0.325***
	(0.085)	(0.043)	(0.072)	(0.070)	(0.048)	(0.042)
Codifiability	-0.387***	0.028	-0.189**	-0.094	0.116**	-0.136***
	(0.089)	(0.046)	(0.075)	(0.075)	(0.052)	(0.046)
Capability	0.162***	-0.295***	-0.089**	0.266***	-0.337***	0.371***
	(0.053)	(0.028)	(0.045)	(0.046)	(0.032)	(0.029)
Km Distance	-0.020	-0.032***	0.000	0.011	-0.033***	0.031***
	(0.017)	(0.009)	(0.014)	(0.014)	(0.010)	(0.009)
Hofstede Culture	0.549***	0.538***	0.795***	-0.382***	0.277***	-0.368***
	(0.051)	(0.027)	(0.043)	(0.044)	(0.031)	(0.028)
Border Effect	-0.146**	-0.035	0.025	-0.119**	-0.038	-0.013
	(0.062)	(0.032)	(0.051)	(0.053)	(0.036)	(0.032)
Months Production	0.007***	-0.004***	0.016***	-0.011***	-0.012***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Proxy Value Added	0.034***	-0.03***	-0.011***	0.034***	-0.035***	0.04***
	(0.005)	(0.002)	(0.004)	(0.004)	(0.003)	(0.002)
Constant	-0.994***	0.514***	-1.465***	0.628***	1.243***	-0.866***
	(0.149)	(0.076)	(0.133)	(0.137)	(0.084)	(0.076)
Observations	2,856	9,656	3,962	3,701	7,577	9,632
Pseudo R-squared	0.10	0.06	0.09	0.07	0.07	0.07

Note: Simple least squares estimation of the log difference of governance proxies, in columns (1)-(6); and probit estimation using mutually exclusive governance categories (see p. 24 for more details), in columns (7)-(12). The number of observations is 12,060 for columns (1)-(6). Standard errors in parentheses; * p<.1; ** p<.05; *** p<.01

comparisons, but there are a few interesting exceptions. Cultural proximity is surprisingly important in modular relationships, while geographical proximity is most important in captive relationships, and country borders are most impeding for relational outsourcing.

In columns (7)-(12) we observe basically the same effects as above, although the sample size changes quite considerably across regressions, which is due to the dependent variable being mutually exclusive in the types. Overall, the theoretical predictions in Table 7 are largely sustained, also in more nuanced test of governance choice.

6 Conclusion

This paper has shown how the theory of the firm can be interpreted in terms of conditional statements that have a relevant application in the global value chain (GVC) literature. We have used the theory of Gereffi et al. (2005) as an organizing framework to obtain a set of empirical predictions, which we then tested using detailed transactions data from the automotive industry. Our empirical method has shown how to obtain proxy variables for five different forms of governance obtained from the GVC literature: market, modular, relational, captive and hierarchy. Furthermore, we have estimated the predictive power of the three key explanatory variables in Gereffi et al. (2005)—namely complexity, transaction codifiability and supplier capability—in the choice of value chain governance. We find largely favorable results that are also robust to different estimation methods.

Appendix

Construction of variables

Component categories are constructed using three levels of detail. The upper most level gives the general area of the car where the component is built in, which we also use for the identification of supplier divisions. The intermediary level indicates the functionality of the component. The lower level category gives a generic description of the component, irrespective of functionality and use. At the intersection of these three levels of detail we define a unique components, which is then classified as complex/noncomplex and codifiable/not codifiable, as show below.

Table 11: Conservative definitions of complexity and codifiability

		Complexity	*Codifiability*
Chassis/Underbody	Axles	1	
	Brakes	1	
	Chassis Components		[a]
	Heat Shielding	1	
	Pressed/Stamped and Metal Parts		
	Seals		1
	Steering System	1	
	Suspension System	1	[a]
	Tires		1
	Wheels		[a]
Electrical/Electronic	ABS/ESC	1	
	Airbags	1	
	Alarm/Immobilizer	1	
	Axles	1	
	Battery & Components		1
	Doors/Tailgate		1
	Driver Assistance System	1	
	Electronic Distribution System	1	
	Engine	1	
	Exhaust System	1	
	Fuel System	1	
	Fuse/Relay/Junction Box		1
	Horns		1
	Ignition	1	
	Infotainment System	1	

	Instrument Cluster	1	
	Lighting	1	1
	Motors	1	
	Pedal Assembly	1	
	Seating		1
	Steering System	1	
	Switches		1
	Thermal System	1	
Exterior	Body Parts		
	Bonding/Adhesives		1
	Bumper & Components		1
	Coatings		1
	Doors/Tailgate		1
	Glass		1
	Lighting		1
	Mirrors		1
	Noise vibration and harshness	1	1
	Pillars	1	
	Pressed/Stamped and Metal Parts		
	Seals		1
	Washer/Wiper Systems		1
Interior	Airbags	1	
	Center Console/Dashboard		
	Doors/Tailgate		1
	Floor		
	Instrument Panel	1	
	Interior Trim		
	Lighting		1
	Mirrors		1
	Noise vibration and harshness	1	
	Pedal Assembly		
	Pillars	1	
	Seating		1
	Steering System		
	Thermal System	1	
Miscellaneous	Bonding/Adhesives		
Powertrain	Axles	1[a]	[a]
	Engine	1	
	Exhaust System	1	
	Filters/Fillers	1	
	Fuel System	1	
	Heat Shielding	1	
	Noise vibration and harshness	1	
	Seals	1	1
	Thermal System	1	
	Transmission	1[a]	[a]

Note: [a] Classifications differ in the generic definition (rounded using sample average).

Instead of using the more detailed but perhaps too conservative classification of component categories, we can regress the governance types directly on indicators of the component categories. Below in Table 3 are the results of a more flexible specification using upper level category dummies, and we see that the direction and even the magnitude of the effects are as expected. Electronics, which are generally complex in cars, are a good predictor for market governance (with a negative sign) as well as relational governance (with a positive sign). Powertrain components are good predictors of modular governance, and miscellaneous components predict captive and hierarchy governance. Interior and exterior components are most often found across market and captive relationships, and chassis and underbodies in captive or hierarchy relationships.

Table 12: Regressions on upper level component categories

	MARKET (1)	MODULAR (2)	RELATION (3)	CAPTIVE (4)	HIERARCH (5)
Chassis/ Underbody	.144***	-.172***	-.305***	.543***	.145***
Electrical/ Electronics	-.526***	-.0264*	.125***	.0107	.113***
Exterior	.708***	-.162***	-.59***	.357***	-.159***
Interior	.502***	-.234***	-.486***	.518***	-.0892***
Miscellaneous	.408***	-.255**	-1.36***	1.54***	.356**
Constant	.717***	2.9***	4.01***	2.02***	10.6***
Observations	57,354	57,354	57,354	57,354	37,516
Adj. R-squared	.0567	.00638	.0331	.0193	.00751

Note: The reference category is Powertrain. * p<.1; ** p<.05; *** p<.01

The supplier capability variable is constructed using data collected on supplier firms, at the headquarters and branch levels. There are many potential candidates to use as proxy, such as R&D investments, age of the firm, size of the firm, profits of the firm, value added in the firm, and many more. We choose to work with a dichotomous firm size divided by firm age variable as explained in Section 4.2. Below we show the results for using alternative proxies of supplier capability, all continuous variables. We see that our capability variable is in fact weaker than the others.

Table 13: Adjusted R-squared of regressions using alternative measures of supplier capability

	MARKET (1)	MODULAR (2)	RELATION (3)	CAPTIVE (4)	HIERARCH (5)
R&D	.0186	.0018	.0078	.0080	.0124
Profits	.0295	.0181	.0145	.0422	.0306
Age	.0600	.0017	.0180	.0182	.0004
Capability [a]	.0008	.0018	.0046	.0014	.0013

Note:[a] Dichotomous size-by-age variable as used above.

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