Industrial and Corporate Change, 2022, Vol. 31, No. 1, 89–111
doi: https://doi.org/10.1093/icc/dtab034
Advance Access Publication Date: 17 June 2021
Original Article

Testing predictions on supplier governance from the global value chains literature

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Abstract

A vast empirical literature analyzes the determinants of the make-or-buy decision. How to organize supplier relationships when the buy option is chosen has received much less attention. The global value chains framework provides testable predictions on the nature of buyer–supplier collaboration. We use a unique transaction-level dataset of outsourced automotive components to study carmakers' choices between four distinct types of supplier governance: market, captive, relational, or modular. The theory formulates predictions based on three characteristics: the complexity or contractibility of a transaction, the capabilities in the supply base, and how objectively codifiable performance requirements are. Our results illustrate that sourcing relationships vary systematically and that the effects of proxies for the three characteristics are in line with the theory.

JEL classification: L22, L23, M11

1. Introduction

A vast literature, both theoretical and empirical, studies the determinants of the make-or-buy decision and the impact of vertical integration on performance. The way sourcing relationships are organized, what one could call "how-to-buy," has received much less attention. Its importance is highlighted in a few seminal papers that study intermediate forms of organization, which Powell (1990) calls networks and Ménard (2013) calls hybrids. The *Nobel Prize* award for Oliver Williamson prominently cites his work on the governance of contractual relationships as an alternative for the choice between markets and hierarchies (Williamson, 1979).

What is lacking, is systematic cross-sectoral evidence for the predictive power of theories of supplier governance. An advantage of the global value chains (GVC) framework proposed by Gereffi *et al.* (2005) is their focus on just three determinants—complexity, codifiability, and capabilities—that are each inspired by existing theories from the economics and management literatures. Complexity is closely related to the extent of contract incompleteness (Maskin and Tirole, 1999). Performance requirements that are difficult to codify, may lead to holdup problems and costly renegotiation that feature prominently in transaction cost economics (TCE) (Bajari and Tadelis, 2001). The emergence of capable suppliers is considered explicitly in Stigler (1951). They are a necessary condition for the investment incentives of outsourcing that are at the heart of the property rights theory (PRT) of Grossman and Hart (1986).

The GVC framework considers optimal governance as a choice between five discrete *relationship types*, also called *modes of governance*. Ranked by decreasing power of the buyer over the supplier, they are hierarchy, captive, relational, modular, and market governance. Market relationships are expected to dominate for less complex products where the price is all important. Hierarchy or internal production is at the other extreme. Outsourcing is not a viable option when products are complex, performance is hard to codify, and existing suppliers are weak. The three intermediate forms are motivated by the authors' earlier work on different industries: the captive form dominates in textiles (Gereffi, 1999); relational in automotive (Humphrey, 2003); modular in electronics (Sturgeon, 2002). A wealth of case study evidence has accumulated in this literature, providing a rich description of the intermediate governance types, but also exploring their boundaries, overlap, and evolution as circumstances change.[1]

Reducing the GVC framework to a choice between five governance modes based on three determinants fails to do justice to the nuanced discussion in Gereffi *et al.* (2005), in particular on the important roles played by power and coordination. However, by investigating whether a systematic relationship exists between the characteristics of an input and the nature of the observed sourcing relationship, we can assess whether sourcing patterns agree with the theoretical predictions. Our main contribution is then to provide systematic econometric evidence on the predictive power of the GVC framework for sourcing relationships. The theory has proven extremely popular to guide case studies of sourcing patterns in individual industries.[2] Researchers have used detailed information on sourcing practices to provide a rich description of the dominant governance mode for many industries. Our empirical work can be considered a cross-industry or cross-product confirmation of the case study evidence.

We study outsourcing in the automotive industry which is one of the most downstream manufacturing sectors (Antràs *et al.*, 2012). Most importantly, it sources a large share of the value of its final product from upstream sectors that differ widely in their characteristics. Because automobile assembly firms need to interact with suppliers from a wide range of industries and source parts that differ greatly in sophistication, it would not be optimal for them to rely on a single form of supplier governance. We indeed find that many automotive parts are sourced in systematically different ways, but our primary interest is not the sourcing practices in this particular industry.[3] Our goal is to test whether the observed variation in buyer–supplier relationships is consistent with the predictions of the GVC framework. In some cases, automotive firms will find it optimal to produce a part in-house, as studied in Monteverde and Teece (1982), but that is the exception. Klier and Rubenstein (2008) describe in detail how most carmakers nowadays choose to outsource a similar, but very broad set of parts and subassemblies.

We do not use industry practices to define governance types, but proceed in three steps. First, we distill a number of testable predictions from the GVC framework on correlations between one or more input characteristics and a governance type. Along the way, we illustrate how the GVC framework can be interpreted as a set of conditional predictions when existing theories of the firm are potentially in conflict. Buyers can modify their supplier governance to compromise when facing two opposing forces in the choice between outsourcing and in-house production. Second, we rely on the literature and the case study evidence to construct for each governance type an indicator that captures a salient feature of the type. We also define proxies for the three key determinants: the complexity and codifiability of parts and the capability of suppliers. Finally, we show that carmakers systematically vary the way they collaborate with suppliers and that the observed patterns strongly accord with the predictions of the theory.

The remainder of the article is organized as follows. In Section 2, we describe the GVC framework and derive testable predictions linking governance modes to input characteristics. In Section 3, we describe the unique transaction-level database on the automotive industry. In Section 4, we discuss the construction of dependent and explanatory variables and the empirical specification. This is followed by the estimation results in Section 5, implications for supplier performance in Section 6, and conclusions in Section 7.

1 The website www.globalvaluechains.org lists 1094 contributions, including 462 journal articles, 96 books, and 165 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 different industries are covered by at least 5 studies.

2 In addition to the many studies listed on the website of the GVC Initiative, the popularity of the GVC framework is also apparent from the 8383 citations to Gereffi *et al.* (2005) (on scholar.google.com, 10/2/2021).

3 A few papers, for example, Mudambi and Helper (1998), Bensaou (1999), and Sturgeon *et al.* (2008), discuss features of buyer–supplier collaboration specifically for the automotive industry.

2. Global value chains in the automotive industry

2.1 The global value chains framework

The GVC framework is widely used in many areas of research. Policymakers and international institutions often appeal to it when framing current policy challenges. Some of its defining features be introduced as follows. Buyers and suppliers in an industry collaborate in a network of input–output relationships that can span a wide geographic area. Activities in a value chain are often wide ranging as well and some generate more value than others. The organization of the chain determines how the total value that is generated is divided among participants, but it also provides paths for firms and countries to increase their contribution and upgrade into higher value activities. The relative power of firms plays a role in the organization and division of surplus. Lead firms in the chain will choose suitable governance modes for suppliers that match the type of activity, industry features, and the local operating environment. Fernandez-Stark and Gereffi (2020), and other chapters in the same volume, provide an accessible and more extensive introduction.

For our application, the most important feature of the framework is the heterogeneity in governance mode of suppliers, that is the way buyer–supplier collaboration is organized. A huge literature studies the vertical integration decision and its determinants. Lafontaine and Slade (2007) review the empirical evidence and Gibbons (2005) provides an integrated theoretical framework that nests several of the most influential theories. It has been recognized, however, that a choice to buy rather than make, is not the end of the story. Sourcing relationships are not one-size fits all and are often tailored to the specific situation. We build on the literature that studies the range of sourcing arrangements between the extremes of make or buy (Table 1). Powell (1990) and Ménard (2013) highlight the varied forms of firm interaction one can observe and how several factors simultaneously influence firms' decisions. Williamson (1979) also discusses potential variations on the buyer–supplier relationship in the TCE framework. In particular, more complicated relationships are distinguished from anonymous market transactions governed by price that dominate the formal make-or-buy models.

The GVC framework provides a way to systematize the study of forms of organization intermediate to the extremes of in-house production (make) or market transactions (buy). Firms deal with an interrelated network of suppliers whose decisions interact. A first distinction advanced by the literature on global commodity chains, see Gereffi and Korzeniewicz (1994) for a range of applications, is between buyer-driven or producer-driven value chains. In producer-driven chains, the suppliers that produce key inputs are the most important and hence their share of the value created and their influence in the industry's organization is also larger. Whether this is optimal, or even feasible, depends on characteristics of activities and transactions, but also on the technological and organizational capabilities of the suppliers.

The governance mode of suppliers is a crucial aspect of the GVC framework that makes it a predictive theory . Gereffi *et al.* (2005) emphasize the importance of three characteristics that are prominent in the management and economic geography literatures, namely: (i) the complexity of a transaction, (ii) how easy it is to objectively define performance, and (iii) the (technological) capabilities present in the supply base.

Table 1. Governance modes considered in different literatures

	Theory of the Firm	Networks	Global Commodity Chains	**Global Value Chains**
	Buy	Market		Market
		Intermediate/ Hybrid/ Network/ Community	Producer-driven	Modular
				Relational
			Buyer-	Captive
Firm boundary	Make	Hierarchy	driven	Hierarchy

These three characteristics jointly determine the optimal way that buyers and suppliers interact. While sacrificing some of the richness of actual relationships, differences in things like the intensity of interaction, both in terms of information exchange and contract scope, the exclusivity of the collaboration, or which side makes crucial technology or design decisions, are used to define a few distinct *types* of relationships. 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 that if transactions are not complex, the other two dimensions loose much of their importance and their requirements are satisfied almost automatically. This leaves the five possible governance types listed in Table 2.

While the GVC taxonomy in Table 2 is somewhat arbitrary, the empirical content of these abstract governance types has been illustrated by a wealth of cases studies that consider nuanced aspects of buyer–supplier collaboration and power dynamics (Antràs, 2019). *Market* transactions are the group of noncomplex transactions or situations that can be governed by contracts with little direct buyer–supplier interaction. Once products or services are standardized, the price mechanism mostly suffices to mediate transactions.[4] At the other extreme are in-house transactions, governed by *Hierarchy.* This form of governance is chosen by necessity if transactions are complex, but no capable suppliers exist and it is impossible to objectively codify performance requirements. It reflects the original insight of Stigler (1951) that for newly established products or industries, firms will not be able to exploit the division of labor and rely on external suppliers until technology matures and specialist suppliers arise.

The nature and the advantages of the three intermediate governance modes will be discussed more extensively below, but we briefly characterize them here. A *Captive* supplier sells virtually all its output to a single buyer, which holds most of the power in the relationship. In terms of relative bargaining strength, captive governance is not all that different from hierarchy. This form of collaboration is chosen when suppliers have only limited capabilities and expertise, but the tasks they need to perform can be specified unambiguously in advance. Where necessary, captive suppliers rely on the buyer for technological and commercial support, but in return they are prohibited from supplying competing firms. This governance form is popular in export processing zones in developing countries were local firms perform assembly tasks and in buyer-driven value chains, such as in the textile industry.

In *Relational* governance, buyer–supplier interaction is intense with frequent information exchanges, similarly as between two divisions of the same firm. Such collaboration is necessary when unforeseeable adjustments need to be implemented regularly or when it is difficult to define performance requirements in advance. In the automobile industry, for example, it is common for employees of some suppliers to be stationed at the design center of the buyer. At the same time, the required sophistication of the supplier in terms of technological or production capabilities would be hampered if it was limited to build expertise only producing for a single buyer. Mol (2005) provides empirical evidence that R&D intensity is increasingly associated with a choice of outsourcing over in-house production. The

Table 2. Determinants of GVC governance

	Complexity of transaction	Ability to codify transactions	Capability of supplier
Market	Low	High[a]	High[a]
Modular	High	High	High
Relational	High	Low	High
Captive	High	High	Low
Hierarchy	High	Low	Low

Source: Adapted from Gereffi *et al.* (2005: 87).

[a]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 indicated for either dimension further down in the table for transactions with high complexity.

4 Other characteristics of a transaction can still influence how pricing is established, for example, fixed prices or cost-plus, but if complexity is sufficiently low this can be arranged contractually and does not require much buyer–supplier interaction (Bajari and Tadelis, 2001).

relational form of governance combines close collaboration between firms with legal independence that provides suppliers with possibilities and incentives to acquire the necessary capabilities.

Finally, *Modular* governance is optimal when supplier capabilities and performance codifiability are high. As in market relationships, the two firms do not interact frequently, but due to high product complexity, contracts and prices alone are not sufficient to govern the relationship. Sturgeon (2002) introduced this term to describe buyer–supplier interactions in the electronics industry. The nature of technology in this industry, in particular the ability to exchange electronic files with detailed specifications of designs and interconnections, facilitates collaboration on highly complex components through an arm's length supply relationship. Different from market settings, modular suppliers tend to possess unique production capabilities and have mastered or developed unique technologies which makes them almost indispensable in a value chain. At the same time, the tasks and activities they contribute can be isolated from the remainder of the work in the value chain such that they can work relatively independently and potentially for a large number of buyers.

2.2 From theory to empirical predictions

2.2.1 Optimal supplier governance based on a single characteristic

We next derive testable implications on the form of supplier governance from the GVC framework. Comparing across rows of Table 2 within the same column, we see that the level of codifiability or capability has no unique predictions as high and low values are both associated with multiple governance types. To obtain unambiguous predictions, it is necessary to limit the comparison to a subset of the types. As there are three determinants, we can focus on conditional predictions. Holding two of the three factors constant, how does variation in the third factor influence the optimal choice? To illustrate this logic, we first discuss how existing tests of the make-or-buy decision in the two most widely used theories of the firm fit into the GVC framework. We turn to the how-to-buy decision afterwards.

Monteverde and Teece (1982), one of the most famous tests of TCE, studies determinants of vertical integration in the US automotive industry in 1976. They limit their sample to sourcing decisions by General Motors and Ford, two American firms known to use competitive bidding to select suppliers and arm's length contracts to govern the subsequent relationship (Helper, 1991). In particular, the sample excludes Japanese producers that had much closer, relational ties with their suppliers (Womack *et al.*, 1990). As a result, the forms of supplier governance that could appear in their sample are hierarchy, for parts produced in-house, and market, captive, or modular for outsourced parts, but not relational. The authors argue that the amount of engineering effort in a part's design is a good proxy for the amount of appropriable quasi rent in a particular relationship, which is similar to the notion of codifiability in the GVC framework. TCE predicts that a high value on this measure makes it more likely that a part is produced in-house and this prediction is confirmed in their empirical analysis. Note, that the prediction is only unambiguous if relational governance is not a relevant governance option, which is indeed likely in the sample they work with.

The analysis in Monteverde and Teece (1982) can also be described as a conditional prediction. First, they limit attention to complex parts as transaction-specific know-how makes contracts incomplete. This eliminates market governance as a viable option. Second, they implicitly assume that the unique expertise of suppliers is not insurmountable such that in-house production of a part by the automaker is a viable strategy. The low capabilities in the automotive supply-base back in 1976 further eliminates relational and modular governance as relevant options.[5] Conditional on these two maintained assumptions—high complexity and low capability—the relevant choice in the GVC framework is between hierarchy and captive governance with the optimal choice determined by codifiability.

5 Helper (1991) describes that in the first decades of the post-war period, most design work on outsourced parts was done upfront by the carmakers who passed the blueprints to the chosen suppliers. Sturgeon *et al.* (2008) describe how the growing technological expertise of suppliers in later years fundamentally changed the organization of the automotive industry.

Monteverde and Teece (1982) explicitly mention that for parts requiring high engineering effort in their development, performance "specs" are often unknown ex ante, which highlights the close link with codifiability.[6]

A second important strand in the make-or-buy literature is the PRT of Grossman and Hart (1986). Its key explanatory variable is the marginal return of the supplier's investment to the joint surplus, relative to that of the buyer. The theory posits that if the supplier's contribution dominates, it is best to outsource the transaction. This enhances the supplier's bargaining power and raises its investment incentives.

As an illustration, Grossman and Hart (1986) provide evidence that automobile liability insurance is more likely to be sold by external insurance brokers (buy), while life insurance tends to be sold by employees of the insurance company (make). This pattern corresponds to the theoretically optimal make-or-buy choice if effort by the sales agent is more important to consumer satisfaction in the former than in the latter segment, which is plausible. Giving a broker control over the client list raises his incentive to look for high quality clients who are more likely to renew their contract, but only if the broker is able to take his clients to another insurance company in case of a dispute. Outsourcing only provides enhanced incentives if the client list is not jointly owned, which is explicitly assumed. Interpreted in the GVC framework, supplier capabilities only distinguish unambiguously between hierarchy and external supplier governance options if the comparison excludes captive governance.

The PRT model is widely used in international economics to explain the choice between arm's length transactions with independent foreign suppliers or engaging in FDI and transacting within the firm.For example, Nunn and Trefler (2013) study situations where investments are explicitly non-contractible (high complexity) and technologically intensive, involving R&D inputs or high human capital (low codifiability). Under those two conditions, the relevant trade-off in the GVC framework is between hierarchy and relational governance with the optimal choice determined by the supplier capabilities. Their evidence supports the prediction as an input is more likely to be sourced in-house if the buyer (importer) makes high investments, especially if the importing industry has more high-productivity firms. In an international trade context, it is natural to exclude captive governance as a viable option. This is necessary to obtain an unambiguous make-or-buy prediction as captive governance, like hierarchy, is attractive when supplier capabilities are low.

The top panel of Table 3 summarizes the logic in the above examples. In particular, it illustrates the necessity of excluding some governance modes from the comparison to have unambiguous predictions. Only then will a low value of the characteristic of interest unambiguously predict in-house production. It also illustrates that lumping all forms of outsourcing into a single "buy" category ignores a lot of interesting variation in the nature of collaboration

Table 3. Deriving testable implications from the GVC governance framework

		Hierarchy	Market	Captive	Relational	Modular
(a) Make-or-buy literature						
TCE: absence of appropriable quasi rents (codifiability)	Monteverde and Teece (1982)	**Low**	High	High	–	High
PRT: Marginal importance of supplier (capability)	Grossman and Hart (1986)	**Low**	High	–	High	High
(b) How-to-buy analysis						
Codifiability of performance requirements		–	High	High	**Low**	High
Capabilities in the supply base		–	High	**Low**	High	High
Complexity of the transaction		–	**Low**	High	High	High

For each characteristic, shown on different lines, only one of the five governance modes has a low predicted value (indicated in bold), while all other modes have a high predicted value. To achieve this situation, one of the governance modes had to be omitted (indicated by -) in each line.

6 Gereffi *et al.* (2005) already discuss the close relationship between the codifiability of performance requirements and the concept of ex-post transaction costs featured in transaction cost economics. If it is possible to describe and for an outside court to verify whether an input meets the required quality, reliability, and timely delivery, ex-post transaction costs will be low as the supply contract can specify these performance features directly even if product characteristics or suppliers' actions are non-contractible.

between buyers and suppliers. Even when firms choose to outsource, they are likely to tailor their collaboration and interactions with suppliers in function of the characteristics of the transaction or the environment.[7]

In the bottom panel of Table 3, the comparison is limited to outsourced transactions omitting instances where hierarchy is chosen. Once a firm decides to go with an external supplier, a low value for each of the three characteristics leads to an unambiguous prediction on the optimal form of supplier governance. Low codifiability predicts relational governance and low supply-chain capabilities predict captive governance. Low complexity predicts market governance which would even be the case if the comparison included in-house transactions. The predictions from the GVC framework regarding the optimal form of supplier governance when hierarchy is not a relevant option can be summarized as follows:

Hypothesis 1: Firms that outsource an input will adjust the way they interact with their suppliers in function of the characteristics of the transaction or the supply-base. In particular,
(a) if the input has low complexity, supplier governance will take the market form;
(b) if capabilities in the supply-base are low, supplier governance will take the captive form;
(c) if codifiability of performance requirements is low, supplier governance will take the relational form.

2.2.2 Optimal supplier governance based on several characteristics simultaneously

Hypothesis 1 summarizes how firms will organize their supplier relationship if any of the three characteristics is low, but only if a transaction is still outsourced. This is straightforward in the case of low complexity as it naturally leads to arm's length market transactions governed by contracts (Maskin and Tirole, 1999). Low complexity makes codifiability or capability almost irrelevant and bringing such a transaction in-house is highly unlikely. The typical challenges in the theory of the firm—moral hazard, holdup, renegotiation, and underinvestment—only arise when contracts are incomplete which is unlikely when complexity is low.

Predictions are less straightforward for low codifiability or capability. If we condition on high complexity, firms need to choose between the four governance options in Table 4. A low value for either characteristic leads to the predictions in Hypothesis 1, but only if the firm does not choose hierarchy. For example, comparing high versus low codifiability, that is choosing between the two columns of Table 4, we only have unambiguous predictions if we condition on the level of capabilities. If capabilities are low, in the top row, hierarchy is a viable choice and the level of codifiability determines the choice between hierarchy or captive sourcing.[8] If capabilities are high, in the bottom row, hierarchy is not a relevant option and low versus high codifiability amounts to a choice between relational and modular governance, in line with Hypothesis 1(c).

Relational governance can be understood as a compromise. Low codifiability is a factor that favors in-house production, but the high capabilities in the supply-base favors outsourcing. The firm adjusts to these opposing incentives by still choosing to outsource, but adjusting the interaction with its supplier in light of the low codifiability. The close

Table 4. Four possibilities governance modes for complex transactions

		Codifiability	
		Low	High
Supply-base capabilities	Low	Make (*Hierarchy*)	Buy (*Captive*)
	High	Buy (*Relational*)	Buy (*Modular*)

7 Similarly, Bajari and Tadelis (2001) study the adjustment of the contract in a market relationship, that is, using fixed-price or cost-plus, depending on the complexity of the transaction.

8 The analysis in Monteverde and Teece (1982) corresponds to this conditional prediction, with the amount of engineering effort in a part's design a proxy for the level of codifiability.

collaboration and continuous flow of information in relational governance mimic the interactions between in-house divisions. Moreover, the frequent contacts reduce the incentives for holdup and renegotiation that are ever-present with low codifiability. In a way, relational governance is a type of sourcing that incorporates elements of hierarchy.

A similar compromise appears when we investigate how governance adjusts to the level of capabilities, comparing between the rows of Table 4. If codifiability is low (left column), low capabilities predict hierarchy and high capabilities relational sourcing.[9] For the comparison in the right column, low capabilities in the supply-base still give the firm an incentive to bring a transaction in-house, but the high codifiability makes this unnecessary. It facilitates outsourcing, making it possible to benefit from specialization. The firm can adjust to the opposing forces and organize its relationship with the supplier to maintain some of the advantages of hierarchy. In this case, it will choose captive governance, in line with Hypothesis 1(b), that gives the buyer all the bargaining power and resembles in-house production.[10] If necessary, the firm will transfer expertise and know-how for production to the unsophisticated supplier, after all it is codifiable, but in return it will request exclusivity.

We thus find that for complex transactions, firms will only choose hierarchy when both codifiability and capability are low. In all other cases, the firm will choose outsourcing but adjust the way of interacting with its supplier to fit the situation. Captive and relational governance both incorporate a different aspect of in-house production: captive governance adopts the exclusivity and transfers of capabilities from the buyer; relational governance adopts the close and repeated collaboration.

Modular governance can then be understood as the way to organize supplier relationships when both high capability and high codifiability make outsourcing optimal, but transactions are too complex for an arm's length relationship solely governed by prices and contracts. Transactions on inputs with higher complexity than in market governance, more capable suppliers than in captive governance, and with performance specifications that are more easily codified than those sourced under relational governance will also take a unique form. Modular governance leaves the supplier with more independence (than in a captive relationship) and interaction is more limited (than in relational governance) which is preferable if capabilities and codifiability are high. The complexity of the product requires more information exchange, quality control, and more sophisticated suppliers. We expect modular suppliers to be relatively important to their clients, but still serve multiple clients with multiple parts to leverage their unique expertise.

Hypothesis 2: An input characterized by a high value of complexity, capability, and codifiability will be outsourced and the firm will use yet another form of interaction with its supplier, called modular governance. It can only be identified separately from each of the other three external governance forms when all characteristics are considered jointly or in pair-wise comparisons.

2.3 Sourcing in the automotive industry

As one of the most downstream manufacturing industries, the automotive industry is an excellent place to study heterogeneity in buyer–supplier interactions (Antràs *et al.*, 2012). Most importantly, cars are complex products that are assembled from a bewildering number of components. Automotive parts differ in technological sophistication, product maturity, returns to scale in production, and scope for differentiation. As a result, carmakers need to interact with virtually all manufacturing industries that each operate under widely varying circumstances. Many case studies in the GVC literature investigate whether the dominant way of sourcing in a particular industry correspond to one of the governance types. Industries are characterized by a few primitives, for example, production technology or product complexity, and researchers investigate whether observed sourcing practices are in line with the optimal or predicted form of governance. Given the uniquely wide range of carmakers' interactions with suppliers, there is no single optimal governance type in the automotive industry. Instead, we can verify whether firms tailor the way they collaborate with different suppliers in accordance with the predictions of the GVC framework.

As automotive suppliers have assumed an increasingly important role in the innovation process, it is well-known that supplier–buyer relationships have gone beyond market type of interactions (Helper, 1991; Hannigan *et al.*, 2015). The buildup of trust (Dyer and Chu, 2000) and other benefits of repeated interactions (Asanuma,

9 Tests of the make-or-buy predictions in the PRT framework, such as Nunn and Trefler (2013), capture this trade-off.

10 Suppliers are legally independent firms, which might give more flexibility in the labor market, but in the product market they are barely more independent than an in-house division (especially from a PRT perspective).

1989) can explain some patterns, but our results will show that even a static model has predictive power for the nature of firm interactions. While Antràs and Chor (2013) emphasize that firms face different incentives to outsource at different points in their supply chain, our results indicate that they have other options than bringing production in-house. Schmitt and Van Biesebroeck (2013) already show that automakers' preferences for supplier proximity vary across parts, but here we document effects on other dimensions than distance in the sourcing patterns as well.

The existing literature already shows that sourcing practices in the automotive industry differ across inputs and suppliers. For example, all carmakers have a few preferred suppliers they collaborate with repeatedly on many of their models.[11] Buyers and suppliers even station some 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. This corresponds to the *relational* mode of governance discussed earlier. At the same time, *captive* supply relationships also have a long history in the automotive industry. Klein (2007) documents the failed attempt of General Motors to preclude Fisher Body from broadening its range of clients (around 1920). The *keiretsu* groups in the Japanese automotive industry are well-known for the subsidiary relationships between a dominant carmaker and its network of smaller supplier firms.[12]

The remaining two types of supplier governance are also found in the industry, in particular for parts at opposite sides of the technological sophistication spectrum. Jacobides *et al.* (2016) describe how in the late 1990s a strategy of modularization of component bundles coupled with the outsourcing of design and production shifted some strategic control of the industry to suppliers. Their description of *full-service* suppliers "that could handle the design, purchasing, and production of all components in a complex subassembly/module" is reminiscent of *modular* suppliers in the electronics industry (Sturgeon, 2002). Some of these firms were formed from spun-off parts divisions of car manufacturers, for example, Visteon from Ford and Delphi from General Motors, while others developed unique capabilities to produce subsystems relatively independently, for example, JCI for seats and Magna for interiors. At the other side of the spectrum, even countries with strong automotive industries, such as Japan and Germany, import increasing amounts of automotive parts from China. The aggregate value of China's parts exports rose from 1.2 billion USD in 1995 to 32.4 billion USD already by 2008 (Amighini, 2012).[13] Such long distance sourcing, especially at a time when the Chinese industry still lagged substantially in technological sophistication, is bound to be dominated by market governance where the competitive advantage of Chinese firms are lower prices for relatively standardized components, for example, wheel, tires, lights, etc.

The observed sourcing patterns are shaped by several forces that tend to feature in distinct theories. As these forces operate simultaneously, it can lead to contradictory predictions. The GVC framework was conceived to synthesize the multitude of factors that firms need to consider. Historically, auto manufacturers based in different countries organized their supply chains somewhat differently, but as the industry matured, sourcing practices converged, as discussed in Womack *et al.* (1990), Helper (1991), Sturgeon *et al.* (2008), and Klier and Rubenstein (2008).

3. Data

3.1 Sourcing transactions

We work with a unique dataset of more than 57,000 sourcing transactions of automotive parts, information that is usually confidential and rarely observed. The data comes from *SupplierBusiness*, a consulting firm to the industry. Each transaction is identified as the unique combination of a car model, supplier firm, and automotive component.

11 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 outside suppliers. The periods of close collaboration were characterized by intense exchange of information and long-term relationships.

12 Ahmadjian and Oxley (2005) describe this close collaboration where carmakers often take an equity position in their suppliers, but also help them to smooth production when demand fluctuates.

13 This corresponds to a 0.7% global market share for China in 1995 rising to 6.7% in 2008. The next year, in 2009, China overtook France to become the fourth largest automotive parts exporter in the world.

The initial sample covers transactions for 421 models that entered production in Europe or North America between 1993 and 2012. They are produced by one of the major car manufacturers, 15 firms in total, and marketed under 52 brands.[14] We keep 350 models in the analysis, dropping observations from niche models, for example, from high-end sports or luxury brands, and some models with few observations. Even though vehicles marketed under different brands are sometimes based on a common platform, they are designed separately and brands tend to have a lot of autonomy regarding purchasing decisions. Exports of cars and light trucks between Europe and North America are relatively unimportant as most vehicles are assembled in the region where they are sold (Sturgeon *et al.*, 2008). Hence, we identify 64 buyers as unique brand-region combinations.[15]

We observe transactions for virtually all globally operating large suppliers, as well as contracts awarded to more than one thousand small and medium size firms located in Europe, North America, and Asia. The vast majority of them are first-tier suppliers that deliver inputs directly to the producer of the final product. We omit many of the smaller suppliers from the sample as we do not observe anything about them apart from their name. Often we also observe too few transactions to determine the nature of their supply relationships. The largest suppliers operate in both regions and they contribute parts to more than one of six broad component areas in a vehicle. Because technologies and commercial contacts with clients will vary along both dimensions, we define 2205 suppliers as unique product division by region combinations. The majority of supplier firms only have a single product division and supply parts only in one region.

Finally, contracts are observed for 213 different automotive parts which are defined using the component categories provided by *SupplierBusiness*. This is a three-level nested classification, with six broad component areas of a vehicle (chassis, powertrain, exterior, interior, electrical, and miscellaneous) at the first level. While most transactions are for detailed components, for example, a brake line or brake caliper, some transactions are for entire subsystems or modules, for example, a transmission or seat, that are supplied in their entirety by a single supplier which will organize a supply chain of its own to produce the module.

We only observe a subset of all sourcing transactions for the models that are included in the analysis, but with 55,354 observations out of a potential total of 74,550 (350 models $\times$ 213 parts) coverage is relatively complete. In some cases, observations will be missing because the part is made in-house by the car manufacturer itself. This is likely to be relatively rare because we omit from the sample parts that many firms produce in-house. Those parts are included in the analysis of Schmitt and Van Biesebroeck (2017) who study the make-or-buy decision. Here we focus on predicting the organization of sourcing relationships for parts that all firms outsource.

The four dependent variables, proxies for the different types of supplier governance, are constructed based on conditional market shares as discussed below. A transaction's contribution to a market share is calculated by multiplying the projected monthly production volume of the model by the expected duration of the contract. Both of these variables are provided in our dataset and reflect expectations before the model enters production.

3.2 Firm information

To construct the proxy for capability and the control variables, we added firm-level information on buyers and suppliers from the *Amadeus* database that covers a broad sample of European firms and subsidiaries. The *Amadeus* database contains information on balance sheet variables, firms' address and industry classification. The matching process to the transaction data is described in more detail in Schmitt and Van Biesebroeck (2013). Unfortunately, the sample is reduced substantially if we include the control variables as only suppliers that account for 16,548 observations could be matched.

Geographic proximity is known to play an important role in the choice of supplier (Schmitt and Van Biesebroeck, 2013). We therefore include the distance from the closest supplier plant to the model's assembly plant and a dummy variable for the presence of a country border between the two plants. Cultural, historic, or institutional ties can also

14 The firms, in order of the number of observations, are Ford, Volkswagen, General Motors, Renault-Nissan, PSA, Daimler, Fiat, BMW, Chrysler, Toyota, Honda, Porsche, Hyundai, Suzuki, Tata. Note that Volkswagen acquired full control of Porsche in 2011 and after our sample period Fiat and Chrysler merged and General Motors sold its Opel/Vauxhall brands to PSA.

15 For example, we consider Ford-Europe and Ford-North America as separate buyers, as well as Volkswagen-Europe and Audi-Europe.

influence the organization of outsourcing relationships. We include a variable of cultural distance measured at the (headquarter) country level using survey data of Hofstede (1980). The index is calculated as the Mahalanobis distance over four dimensions: individualism, power distance, uncertainty avoidance, and masculinity.

We experimented with two variables to control for the production technology of the supplier, capital intensity (total value of assets per employee), and a proxy for the return on assets (operating revenues over total assets). As the first variable almost invariably became statistically insignificant if the second one was included, we only kept the return on assets proxy. A final control variable, the contract length, is observed at the model level in the sourcing data and measured by the number of months between the start and end date of production. It is expected to capture the uncertainty in a buyer–supplier relation.

4. Empirical framework

We estimate the likelihood that buyers choose a particular form of supplier governance as a function of the three explanatory variables of interest: complexity, codifiability, and supplier capabilities. As the governance types are not directly observed in the data set, we need to rely on proxies for both the dependent and explanatory variables. It is important to emphasize that the dependent variables are constructed using only observed sourcing patterns in the data, for example, the frequency of collaboration or concentration of buyers or products. In contrast, the explanatory variables do not use any information from sourcing patterns, but only rely on characteristics of parts or suppliers.[16]

4.1 Specification

If the various governance types (indexed by k) could be unambiguously identified in the data, as is the case when studying the make-or-buy decision, one could simply define a categorical variable that takes a different value for each type. The latent profit obtained in each case could be modeled as a linear function of the three explanatory variables of interest, a few control variables, and an unobservable error term. With an assumption on the distribution of the error one could derive an expression for the probability that a buyer chooses each of the types and estimate, for example, a multinomial logit model.

Unfortunately, the type of governance is not observed directly and we need to rely on proxies to identify it. 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 four distinct types. Rather than partitioning relationships exhaustively in four groups, we construct for all observations four continuous variables that are each monotonically related to one of the governance types. Note that transactions that use *hierarchy* (the fifth governance mode) are by construction excluded from our sample of outsourced parts.

The regressions we estimate take the following form:

$$y^k_{bsp} = \beta_{1k} complex_p + \beta_{2k} codify_p + \beta_{3k} capable_s + controls + \epsilon_{bsp}, \qquad (1)$$

with $y^k = \{market_{sp}, captive_{bsp}, relational_{bsp}, modular_{bs}\}$. The actual variables used vary at the levels indicated by the subscripts in equation (1) and we describe in the next subsections how they are constructed and what motivated these choices. We estimate four sets of coefficients $\{\beta_1, \beta_2, \beta_3\}$, one for each governance type, using the full sample of transactions bsp, which are unique buyer–supplier–product triplets.[17]

When we use one dependent variable, say $y^k = market$, all transactions that are sourced using one of the three nonmarket types are expected to have relatively low values for this variable. Only for an explanatory variable that is high for market governance and low for all three other types, or vice versa, do we expect a systematic relationship. In Table 3, we see that this is the case for complexity, which is expected to be low for market and high for captive, relational, and modular. We thus expect a negative sign on the complexity variable in the market regression, as predicted by Hypothesis 1(a). There are no clear predictions for codifiability or capability, which are expected to be high for

16 It mirrors the approach in Monteverde and Teece (1982) who surveyed experts to independently assess engineering requirements of the design and production of components as a predictor of outsourcing decision.

17 Observations are really identified by *bm* rather than *b*—the specific car or light truck model *m* produced by buyer *b*—but explanatory and control variables only use information on the buyers, ignoring individual models. In the construction of the dependent variables (below), we always sum over all models of a buyer.

market transactions, but also for some of the other types of transactions. The other unambiguous sign predictions are a negative effect on capability in the captive regression and on codifiability in the relational regression, as predicted by Hypotheses 1(b) and 1(c).

Pairwise comparisons between governance types generate several more unambiguous predictions. In a sample of only modular and captive transactions, we would expect a positive relationship between capability and the likelihood of modular governance. Hypothesis 2 further predicts a positive sign on complexity or codifiability if the sample includes modular and either market or relational transactions. 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:

$$\begin{aligned} y^k_{bsp} - y^l_{bsp} = (\beta_{1k} - \beta_{1l}) * complex_p + (\beta_{2k} - \beta_{2l}) * codify_p \\ +(\beta_{3k} - \beta_{3l}) * capable_s + controls + \tilde{\epsilon}_{bsp}. \end{aligned} \quad (2)$$

For example, using as dependent variable $(modular_{bs} - captive_{bsp})$ makes it possible to test whether the prediction $(\beta_{3modular} - \beta_{3captive}) > 0$ holds.

An alternative way to make pairwise comparisons is to classify transactions as one of the two types, depending on the values it attains in the distribution of both dependent variables. To avoid misclassifications, we only keep transactions with a high value for one dependent variable and a low value for the other, omitting those that have values on the same side of the median for both dependent variables. Pairwise comparisons can then simply be performed with a probit regression on the subsample of transactions assigned to one of the two types under consideration:

$$Pr[y^k_{bsp} > p^k_{50\%} \ \text{ and } \ y^l_{bsp} < p^l_{50\%}] = \Phi(\beta_{1kl} complex_p + \beta_{2kl} codify_p + \beta_{3kl} capable_s + controls), \quad (3)$$

with $\Phi(.)$ the normal distribution function and $p^k_{50\%}$ the median value for variable y^k_{bsp} in the full sample and similarly for type l.

4.2 Dependent variables: four types of supplier governance

The heterogeneity of observed buyer–supplier relationships is illustrated in Table 5 for three suppliers in our dataset. It shows the fraction of sales going to a supplier's most important buyer, the supplier's market share in the full sample for its principal product, and the share of a product's market share accounted for by an average client. The large differences between suppliers along these dimensions suggest that lumping together all forms of outsourcing, as in the make-or-buy literature, hides a lot of interesting variation.

In empirical work on the make-or-buy decision, the legal definition of ownership straightforwardly distinguishes in-house production from outsourcing.[18] In our case, we need a mapping from the observable features of buyer–supplier interactions to a set of governance types. Preferably, this mapping should apply in a variety of economic settings. Rather than partitioning all observations exhaustively in four groups, we associate each of the four types with a proxy variable that captures an essential feature of the governance type. For example, captive suppliers receive

Table 5. Examples of heterogeneity in buyer–supplier interactions

Supplier name	Most important component	Fraction of sales accounted for by most important buyer	Market share of this supplier for its primary product	Market share for this product of firm's average buyer
Smarteq	Infotainment	97%	1%	19%
Gallino Plasturgia	Bumper	15%	1%	3%
Wescast	Exhaust manifolds	34%	39%	8%

Note: These market shares are calculated in the full sample of transactions that we observe.

18 Schmitt and Van Biesebroeck (2017) propose a way to expand the sample and study the make-or-buy decision with the same dataset.

Table 6. Definitions of the dependent variables that proxy for the governance types

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

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

technological support, but sell exclusivity (or mostly) to a single buyer. The number of clients will vary inversely with the probability that the relationship is of the captive type. These continuous proxy variables are the dependent variables in specification (1) and replace the vertical integration dummy in the make-or-buy literature.

To define variables that are monotonically increasing in the likelihood that a transaction is of a given governance type, we took inspiration from the industry case studies in the GVC literature, but still followed an approach that works generically. Looking across all transactions indexed by *bmps*, we calculate the frequency that they involve the same supplier–buyer–product (or similar) combination and normalize this by the frequency that the corresponding supplier, product, or supplier–product combination occurs. We measure these frequencies not simply by the number of transactions, which would give them a probability interpretation, but weigh them by the production volume of the relevant model, which gives them a market share interpretation. We propose as proxy for each governance type a ratio of two shares, using the case literature to guide us in the selection of the different shares. Each proxy measures how concentrated contracting is along the dimension intuitively most closely connected with a particular governance type (in the numerator) and normalizes this by the concentration along another dimension (in the denominator).

The market shares that enter these calculations are listed Table 6. They are the total market shares of the seller or product over the entire sample (σ_s and σ_p), the market share of a particular buyer–supplier pair over all products they trade (σ_{bs}), and the same share limited to a single product p (σ_{bsp}), but still summing over all models. We take the inverse of some ratios such that a higher value is always associated with a higher probability for the type. Table A1 in the Appendix lists the mean and standard deviations of all four variables.

Captive relationships are characterized by a high concentration of sales of a particular product–supplier combination to a single buyer, as in Ahmadjian and Oxley (2005), that is, high $ln(\sigma_{bps}/\sigma_{ps})$.[19,20] 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 in the supplier's overall sales is limited, that is, σ_{bsp}/σ_s is low (Sturgeon *et al.*, 2008). It differs from the inverse measure of *Captive* governance, to the extent that a supplier has a large number of products

19 Some producer-driven industries are characterized by captive downstream retailers (Gereffi, 1999). In buyer-driven industries like the automotive sector, captive upstream suppliers are more relevant.

20 As a robustness check, we have also characterized *Captive* relationships by a small market share for the supplier relative to the buyer it sells to, that is, low σ_s/σ_b or high $-(ln\sigma_b/\sigma_s)$. Results in the working paper indicate that this alternative dependent variable shows similar correlations with the three GVC determinants.

in its portfolio. A supplier will operate with a similar 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 account for a relative small fraction of a supplier's overall market share, but individual components might dominate a buyer–supplier relationship (Humphrey, 2003). The ratio is similar to the measure for *Captive* relationships, but defined inversely and not defined by product, but summed over all of the product–markets a supplier operates in. Finally, *Market* relationships will have low supplier market shares relative to the overall product market (Stigler, 1951). Competition is strong, if products are relatively common.

4.3 Explanatory variables: characteristics of parts and suppliers

4.3.1 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. We measure the complexity of individual parts by the number of subcategories that are contained in the module that a part belongs to. The objective is not to capture the technological sophistication required to produce the part, but the extent and intensity of required interactions with the buyer and with suppliers of other parts that are 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 (Bajari and Tadelis, 2001).

We count the number of subcategories in each module and all parts that belong to that module receive the same value. As we do not want to give this simple count a cardinal interpretation of complexity, we transform the continuous proxy into a dummy variable that indicates whether it has a value below or above the sample median.[21] Table A1 in the Appendix shows the means and standard deviations of all three explanatory variables. About 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 value exactly equal to the median.

4.3.2 Codifiability

A useful, but narrow definition of codifiability is "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: 79) This definition involves the codifiability of the component itself, as well as the interactions between the buyer and supplier. More generally, a component is codifiable if the buyer is able to specify in advance and in a readily verifiable way the performance characteristics that a part has to meet. If a part occurs in several modules in different places of a vehicle, it is less application-specific and more likely to appear in multiple outsourcing relationships. Standardization of its performance requirements will be more valuable, as it can generate scale economies and allow for more competition between suppliers. While components might still be complex, for example, because they interact with many other parts, the standardization of functionality makes them less model-specific and reduces the scope for ex post holdup.

To operationalize this insight, we again rely on the hierarchical way *SupplierBusiness* has organized the components in the dataset. Transactions are first classified into a broad *area*, such as the engine, body and trim, interior, or chassis. Within each area, there is a second level of subcategories by function, called *modules*, such as a bumper, braking system, console, etc. In the third level of detail, 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 (not necessarily produced by the same supplier), common examples include bearings, gaskets, and sensors. One measure of codifiability is a count of the number of times a component occurs in distinct third-level subcategories over the entire set of 213 components that we observe. To make the variable less sensitive to outliers

21 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.

and facilitate interpretation of the regression coefficients, we again code it as one or zero, relative to the median value.

We experimented with an alternative measure using information from outside the dataset classifying a component as codifiable if it is 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 increasing sophistication of electric and electronic systems in cars which makes exchange of extensive information between assemblers and suppliers more important, but also more feasible. An objective is to move away from proprietary solutions, prevalent in the car industry, and to optimize the interfaces of and interactions between components.[22] Results using this variable had almost always the same signs as for the benchmark codifiability variable, but it reduced the sample size as not all components could be classified unambiguously.

4.3.3 Capability

The third predictor for the type of governance is supplier capability which we measure by firm size. We draw inspiration from the literature on equilibrium market selection which explains firm-level growth from differences in innate productivity that firms discover themselves from past market success. More productive firms will gradually learn their ability, grow over time, and survive for a longer period. Haltiwanger *et al.* (2013) show that it is important to control for age as firms need time to reach their desired size.

This selection mechanism is relevant for the evolution of the automotive industry over the last 20 years, as it consolidated through mergers and supplier exit. The industry also globalized, further allowing the most efficient firms to increase in size (Sturgeon *et al.*, 2008). A related literature on firm capability and learning argues that firms compete on the basis of internal resources that 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. R&D expenditures, for example, also tend to increase strongly with firm size.

We measure size using turnover (operating revenues) and divide by the age of the main EU branch or regional headquarters, both are 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 components. We again make the variable binary by comparing it with the (full) 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.

5. Results

Table 7 contains the estimates for specification (1) based on a separate regression for each governance type. In the top panel, we summarize the theoretical predictions from the GVC framework for the relationship between each type and the three key explanatory variables. The shaded areas indicate instances with an unambiguous sign prediction on the full sample of transactions. This occurs when only one of the four governance types is associated with a low value of a characteristic, as summarized in Hypothesis 1.

In the first panel, only the characteristic that can be unambiguously related to a governance type is included in the regressions. All three estimates have the predicted sign. Market governance is negatively related to complexity, as the more sophisticated governance modes are only chosen if complexity is high. The captivity proxy is negatively related to supplier capability, although the coefficient is not significantly different from zero. The relational proxy is negatively and very strongly related to codifiability. 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. The proxy for modular governance is positively correlated with a dummy variable for simultaneously high values of capability and codifiability. Only market relationships are also predicted to combine high capability and high codifiability, but in that case these characteristics are not necessarily high in an absolute sense, as transactions are not complex.

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

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
	(1a)	(2a)	(3a)	(4a)
Complexity	−0.604***			
	(0.021)			
Capability		−0.007		
		(0.023)		
Codifiability			−0.500***	
			(0.030)	
Capability and codifiability				0.080**
				(0.035)
Observations	15,331	15,331	15,331	15,331
	(1b)	(2b)	(3b)	(4b)
Complexity	−0.500***	−0.314***	0.373***	0.089**
	(0.034)	(0.037)	(0.043)	(0.037)
Capability	0.015	−0.010	0.091***	0.027
	(0.020)	(0.023)	(0.026)	(0.022)
Codifiability	0.147***	−0.100*	−0.192***	−0.003
	(0.036)	(0.056)	(0.046)	(0.039)
Observations	15,331	15,331	15,331	15,331
Adjusted R^2	0.051	0.015	0.023	0.001
	(1c)	(2c)	(3c)	(4c)
Complexity	−0.534***	−0.354***	0.406***	0.117***
	(0.037)	(0.041)	(0.046)	(0.040)
Capability	−0.136***	−0.155***	0.409***	0.176***
	(0.024)	(0.027)	(0.031)	(0.026)
Codifiability	0.065*	−0.148**	−0.121**	0.006
	(0.039)	(0.081)	(0.050)	(0.042)
Distance	0.077***	0.005	−0.003	−0.010
	(0.007)	(0.008)	(0.009)	(0.008)
Hofstede culture	−0.119***	0.408***	−0.260***	−0.585***
	(0.023)	(0.026)	(0.029)	(0.025)
Border effect	0.068***	−0.098***	−0.005	0.116***
	(0.027)	(0.030)	(0.034)	(0.029)
Contract length	−0.007***	−0.006***	0.013***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)
Return on assets	−0.045***	−0.024***	0.047***	0.017***
	(0.002)	(0.002)	(0.002)	(0.002)
Observations	12,241	12,241	12,241	12,241
Adjusted R^2	0.133	0.052	0.096	0.072

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

Results in the second panel confirm these findings for specifications that include all three explanatory variables simultaneously. Two of the three shaded point estimates are 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. With all control variables included, results reported in the third panel, none of the coefficients of interest change sign, and the coefficient on capability in column (2) even becomes statistically significant.[23] We now discuss the results in greater detail by governance type.

5.1 Market governance

The proxy for market governance shows a strong negative relationship with complexity, while the theory also predicts a high level of codifiability and supplier capability. To some extent, this is almost by construction as the reverse would be difficult to imagine for transactions that are not complex. Still, there is no 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 codifiability, as modular or captive transactions are also predicted to have high codifiability.

We resolve this ambiguity by making pairwise comparisons and report those results in Table 8. The theoretical predictions are again summarized at the top and the more numerous sign predictions are shaded. Results in panel (a) use specification (2), that is with the differences between two continuous governance proxies as dependent variables; results in panel (b) use dummy dependent variables according to specification (3). Across the 96 coefficient estimates reported in Table 8, there are only four instances where the coefficients in the two panels have a different sign, and only in a single instance is the difference statistically significant.

In pairwise comparisons of market governance relative to the three alternatives, the complexity variable keeps its negative estimate in all six cases. Note that due to the definition of the dependent variable in column (4)—modular-versus-market instead of market-versus-modular—all signs should be reversed to compare with the first two columns that include market transactions. It is intuitive that coefficient is smallest in the comparison with captive transactions, in column (1), suggesting that the difference in complexity is less pronounced.

In the comparison with captive governance, market transactions also have the predicted positive sign on capability. The same is true for codifiability in column (2), for the comparison with relational transactions. We already found these effects in the unconditional comparison in Table 7, but the point estimates are now higher and estimated more precisely. Finally, capability and codifiability are expected to be high for both market and modular governance, which are compared in column (4). The results indicate that supplier capabilities are especially high for modular, while codifiability is higher for market. It is intuitive that noncomplex components are fairly easy to standardize and do not require such high supplier capabilities.

Some of the control variables also show intuitive patterns. In particular, market relationships that are governed by contracts should be more suitable for international trade and shipping over great distances. Distance has a positive and significant coefficient in column (1c) of Table 7 and all estimates in Table 8 confirm this pattern. Market governance is also systematically associated with contracts of shorter duration and contracts that generate a lower return on assets.

5.2 Captive governance

The results in Table 7 that suppliers are more likely to be captive when their capabilities are low are in line with the theoretical prediction. The estimates in columns (1, 3), and (5) of Table 8 confirm this pattern in all pairwise comparisons.[24]

23 Because corporate strategy might influence governance choices, we also estimated a specification with region-fixed effects (for the supplier and buyer) or even with firm-fixed effects for the buyer as additional controls. Some of these patterns are interesting in their own right, but it did not influence the signs and significance of the three explanatory variables of interest.

24 The positive sign on capability in column (1) is also in line with the prediction, because the sign would reverse if the dependent variable were defined as (*captive* – *market*) instead of (*market* – *captive*).

Table 8. Results for pairwise comparisons

First type = 1 Second type = 0	Market vs. captive	Market vs. relational	Captive vs. relational	Modular vs. market	Modular vs. captive	Modular vs. relational
Complexity	Low vs. high	Low vs. high	Both high	High vs. low	Both high	Both high
Capability	High vs. low	Both high	Low vs. high	Both high	High vs. low	Both high
Codifiability	Both high	High vs. low	High vs. low	Both high	Both high	High vs. low
(a) Dependent variables are difference of two continuous variables						
	(1a)	(2a)	(3a)	(4a)	(5a)	(6a)
Complexity	−0.180***	−0.940***	−0.760***	0.651***	0.471***	−0.289***
	(0.043)	(0.073)	(0.083)	(0.061)	(0.078)	(0.030)
Capability	0.052*	−0.544***	−0.563***	0.312***	0.331***	−0.232***
	(0.028)	(0.048)	(0.054)	(0.040)	(0.051)	(0.020)
Codifiability	0.214***	0.186**	0.027	−0.059	0.154*	0.127***
	(0.046)	(0.078)	(0.088)	(0.065)	(0.083)	(0.032)
Distance	0.072***	0.080***	0.008	−0.085***	0.015	−0.007
	(0.009)	(0.015)	(0.016)	(0.012)	(0.016)	(0.006)
Hofstede culture	−0.527***	0.140***	0.668***	−0.469***	−0.993***	−0.326***
	(0.027)	(0.046)	(0.052)	(0.038)	(0.049)	(0.019)
Border effect	0.166***	0.072	−0.093	0.038	0.214***	0.121***
	(0.032)	(0.054)	(0.061)	(0.045)	(0.057)	(0.022)
Contract length	−0.001	−0.020***	−0.019***	0.014***	0.013***	−0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Return on assets	−0.021***	−0.092***	−0.072***	0.062***	0.041***	−0.030***
	(0.002)	(0.004)	(0.004)	(0.003)	(0.004)	(0.002)
Observations	12,241	12,241	12,241	12,241	12,241	12,241
Adjusted R^2	0.051	0.130	0.078	0.105	0.059	0.108
(b) Dependent variables are discrete						
	(1b)	(2b)	(3b)	(4b)	(5b)	(6b)
Complexity	−0.147**	−0.360***	−0.250***	0.314***	0.156***	−0.221***
	(0.064)	(0.046)	(0.042)	(0.046)	(0.042)	(0.086)
Capability	0.112***	−0.287***	−0.306***	0.246***	0.218***	−0.216***
	(0.042)	(0.031)	(0.029)	(0.034)	(0.027)	(0.054)
Codifiability	0.435***	0.395***	0.124***	−0.386***	−0.019	0.391***
	(0.068)	(0.049)	(0.045)	(0.054)	(0.044)	(0.091)
Distance	0.079***	0.018***	−0.011	−0.023**	0.011	0.016
	(0.014)	(0.009)	(0.009)	(0.011)	(0.009)	(0.017)
Hofstede culture	−0.436***	0.127***	0.363***	−0.434***	−0.507***	−0.558***
	(0.040)	(0.030)	(0.028)	(0.034)	(0.026)	(0.051)
Border effect	0.257***	0.106***	−0.034	−0.084**	0.084***	0.133**
	(0.047)	(0.035)	(0.032)	(0.038)	(0.031)	(0.062)
Contract length	−0.004***	−0.012***	−0.008***	0.011***	0.005***	−0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Return on assets	−0.031***	−0.049***	−0.035***	0.048***	0.024***	−0.028***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
Observations	3705	8857	9862	7501	9556	2816
Quasi-R^2	0.069	0.092	0.068	0.084	0.060	0.135

Note: In panel (a), the dependent variables are pairwise differences between the variables defined in Table 6 and estimation is with OLS. Panel (b) reports results 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.

While complexity and codifiability are also predicted to be high for captive relationships, the point estimates on these two characteristics are negative in Table 7. It does not necessarily conflict with the theory as some other governance types are also expected to have high values for them which might very well even be higher than for captive relationships. The sign on codifiability turns positive in columns (3a) and (3b) in 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. Codifiability appears to be similar for modular relationships, but notably higher for market relationships. Transactions under captive governance show much lower complexity than relational or modular transactions, but somewhat higher than for market transactions.

Three control variable that capture geographic or cultural distance show a systematically negative relationship with captive governance. The negative association with physical distance or the presence of country borders is consistent with frequent colocation of captive suppliers with the assembly plant. The strongest (positive) correlation is with the Hofstede cultural distance. Carmakers are found to maintain stronger control over suppliers that come from culturally very distinct countries.

5.3 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, 3), and (6) of Table 8.[25] 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 other 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.

The nature of technology in the automotive sector tends to favor relational governance. 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 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 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 (Mol, 2005). It is not surprising that these types of close relationships are distinguished from other relationships in our sample by simultaneously high complexity, high supplier capabilities, and low codifiability.

In terms of control variables, it is also intuitive that these collaborative relationships are associated with low values of cultural distance than for market or captive, longer contract length, and high return on assets.

5.4 Modular governance

In the comparison across all governance types, there were no unique predictions for modular relationships. The values for all three characteristics should be high, but that is always the case for at least one other governance type as well. Hypothesis 2 states that conditional or pairwise comparisons with other governance modes are needed to identify modular governance relationships. Estimates in columns (4)–(6) confirm the expected signs: positive and precisely estimated coefficients on complexity in the modular versus market comparison; on capability in the modular versus captive comparison; and on codifiability in the modular versus relational comparison.

It is not directly predicted by the theory, but it is intuitive that modular governance involves more capable suppliers than market governance. In the latter case, suppliers only need to be capable enough to produce noncomplex parts, which might not require very high capabilities in absolute terms. Modular relationships also involve more complex components than captive relationships, which is reasonable given the low capabilities under captive governance.

25 In each of the three pairwise comparisons, the dependent variable is defined to be low for relational governance.

Table 9. Performance 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%
R&D intensity (% of sales)	2.3%	2.6%	5.8%	6.3%
R&D expenditure (thousands €)	52	204	261	349

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.

6. Supplier governance over a component's lifecycle

The results suggest that most of the theoretical predictions at the level of individual transactions, that is, the nature of the sourcing relationship between a buyer and supplier for a particular part, are strongly supported in the data. We now take a step back to see what this implies for differences between suppliers. We first classify all transactions into one of the four governance types, based on which of the proxies attains the highest value within its respective distribution. Next, we classify each supplier to the governance type that occurs most frequently across all its transactions.

In Table 9, we show the average values for two performance characteristics across all suppliers allocated to a type. The profit margin as a percentage of sales is by far the highest for suppliers that are mostly engaged in modular relationships, and it is lowest for market and captive suppliers. In contrast, expenditures on R&D are highest for captive suppliers and lowest for market suppliers.

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 exists (Stigler, 1951). Once performance standards become codified, production can be outsourced to captive suppliers, but the buyers structure the collaboration to capture most of the surplus (Helper, 1991). Captive suppliers initially receive training and knowledge transfers from their clients, but they invest strongly in R&D to build up their own capabilities. Their objective is to graduate to a modular, more independent type of governance, that is much more profitable for suppliers. However, as the technology continues to mature, other suppliers also acquire the necessary expertise and inevitably products become standardized, such that market relationships governed by prices and contracts become feasible and profit margins of suppliers evaporate again.

In the above evolution, codifiability increases before capabilities, but the order can also be reversed. In some cases, highly capable and specialized suppliers possess crucial expertise and they introduce new products or new functionalities. Suppliers spend a lot of resources on R&D, but are able to generate a decent profit margin. At first, collaboration with carmakers takes the relational form. The close collaboration that the new technology requires makes it only feasible for suppliers to sell their services to a few 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 it still requires highly capable suppliers to standardize the technology. As this process continues, eventually the technology will lose its complexity. Increasingly, suppliers will be chosen based on price and relationships will be governed by contracts. In sum, governance becomes more market-like, which lowers supplier profits.

7. Conclusions

The main objective of our study was to illustrate that empirical work can and should go beyond firms' make-or-buy decisions. The GVC framework distinguishes five stylized governance types, but in the analysis we exclude in-house production (*hierarchy*) as that choice is not observed in our dataset of supply contracts. In earlier work, we used the absolute frequency that a transaction is observed in the dataset 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, results in Schmitt and Van Biesebroeck (2017) show that the effects of the same three explanatory variables also have the predicted signs on the make-or-buy decisions.

A key takeaway from the analysis in this article is that it is possible to distinguish between different “buy” relationships and that the predictive power of the explanatory variables extends from the make-or-buy to the how-to-buy decision. As one of the most downstream manufacturing industries, the automotive industry sources inputs from a wide range of supplier industries. We find that car producers adjust their way of sourcing in a predictable way. The results support the GVC predictions as summarized in the first hypothesis:

- Hypothesis 1(a): Less complex components are sourced through arm’s length *market* interactions and more intricate supplier governance is only chosen when complexity is high.
- Hypothesis 1(b): 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.
- Hypothesis 1(c): Suppliers with low capabilities are more likely to work in a *captive* relationship where they are beholden to a large buyer, but receive technological or commercial support.

The theory predicts that even complex components are only produced in-house if both codifiability and supplier capability are low. If only one of these dimensions is low, outsourcing is still feasible, but the collaboration with suppliers will take a particular form. In a captive relationship, the buyer retains almost all of the bargaining power and will have the same strong investment incentives that the PRT assigns to in-house production. In relational governance, the supplier and buyer interact almost as closely as an in-house division, which retains the advantages that the TCE assigns to in-house production. Which leads us to the final takeaway:

- Hypothesis 2: When both codifiability and capability are high, both TCE and PRT theories predict outsourcing. If, moreover, transactions are highly complex, the GVC framework calls for *modular* governance which gives more design responsibility and bargaining power to suppliers than in market relationship governed by contract.

Assigning suppliers to the governance type they use most frequently reveals distinct patterns in performance. The differences are consistent with R&D expenditures leading to higher capabilities and an evolution in governance. They are also consistent with technologies becoming more standardized over their lifecycle, raising the profitability of suppliers as they gain greater independence, until eventually products become standardized and profits are competed away. Such a dynamic interpretation of the evolution of sourcing is appealing, but not explicitly shown. We leave a rigorous exploration of such sourcing dynamics for future work.

A final thing to consider is the generalizability of our findings. The GVC predictions are supported in the automotive industry, but would they also hold in other settings? To some extent this question is moot. A wealth of case studies covering a broad range of industries has already shown the usefulness of the GVC framework to understand sourcing practices. In most industries, only a few important inputs need to be sourced and one governance mode will be best suited. We do however, see two interesting questions for future research.

The vast range of input-supplying industries that automakers need to interact makes it optimal for them to vary their supplier interactions. Some (relational) suppliers will station employees in buyer’s design headquarter, while other (captive) suppliers are prohibited from working with competitors. This adjustment happens even as external forces, for example, political pressure, also influence sourcing practices (Sturgeon *et al.*, 2008). It would be interesting to see whether the patterns also hold in other industries that need to interacts with a broad range of suppliers. For example, the much more strict regulatory regime in the health care industry might severely reduce hospitals’ ability to tailor their sourcing practices to the situation.

Another interesting direction of inquiry would be to investigate whether an industry that for the majority of its inputs uses one governance mode, is still able to adjust its practices for a minority of inputs where another type of relationship would be more appropriate. If a firm specializes in one governance mode, would institutional norms, self-imposed rules, or even habits lead it to use the same form of buyer–supplier interaction everywhere? If that is the case, would that be profit maximizing as advantages to governance specialization could outweigh the performance penalty associated with an imperfect governance fit (Leiblein *et al.*, 2002)?

Acknowledgments

We would like to thank participants in seminars at Bielefeld, KU Leuven, LSE, the NBER, and Utrecht, as well as Gary Gereffi, Tim Sturgeon, Steve Tadelis, Frank Verboven, and two anonymous referees for their comments. Financial support by the KU Leuven Methusalem Project on the Granular Economy and the Fonds Wetenschappelijk Onderzoek—Vlaanderen (FWO) and the Fonds de la Recherche Scientifique—FNRS under EOS Project No. G0G4318N (EOS ID 30784531) and Project No. G073619N is gratefully acknowledged.

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Appendix

Table A 1 Summary statistics

	Number of observations	Mean	Standard deviation
(a) Dependent variables			
Market	15,331	0.625	1.297
Modular	15,331	2.812	1.383
Relational	15,331	3.963	1.628
Captive	15,331	−2.333	1.451
(b) Key explanatory variables			
Complexity	15,331	0.581	0.470
Capability	15,331	0.453	0.498
Codifiability	15,331	0.357	0.437
(c) Control variables			
Distance	12,241	0.713	1.697
Hofstede culture	12,241	0.418	0.493
Border effect	12,241	0.301	0.459
Contract length	12,241	82.15	19.477
Return on assets	12,241	2.985	6.228