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REGULAR ARTICLE

The Influence of value chain governance on innovation performance: A study of Italian suppliers

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Abstract
This paper explores how value chain governance affects the innovation performance of suppliers of intermediate products. We take advantage of a unique dataset of Italian firms to identify governance regimes based on the perceived levels of technological capabilities of suppliers and explicit coordination in the value chain. Our results indicate that 'modular' value chain governance is more conducive to innovation for suppliers, especially when these firms have medium capability levels. Conversely, market-based governance modes relate strongly to lower innovativeness amongst suppliers, particularly those with lower capabilities. These patterns are also reflected in the sales of innovative products. Our results go partially against other findings in the GVC literature, whereby relational value chains are usually seen as providing the most favorable environment for learning and innovation.

Keywords Global value chains · Suppliers · Innovation · Technological capabilities

JEL Classification F14 · O30

1 Introduction

The evidence that the vast majority of firms in the economy serve as suppliers to other companies is not surprising.[1] These businesses are relevant not only due to their weight in total production but especially because they form the backbone of

[1] For instance, Dhyne & Rubínová (2016) report that 75% of Dutch firms sell products to other companies, with an average manufacturing firm relying on 48 buyers and 60 suppliers.

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value chains, therefore shaping industries and national economies. Despite this clear importance, only a small – albeit growing – share of the theoretical and empirical economic literature considers the peculiar nature of suppliers and the fact that they operate in environments that are not reliant on selling to final markets. Consequently, their performance, production, and learning routines can also substantially differ.

Following one of the streams of literature that does account for such issues, i.e. the Global Value Chains (hereinafter, GVCs) literature, this paper explores how the specific governance regime of value chains may affect the innovation performances of Italian suppliers.[2] When the complexity of value chain relationships becomes too high, inter-firm linkages tend to depart from arm's-length market transactions because firms increasingly have to rely on coordination mechanisms that go beyond price-quantity setting (Gereffi et al., 2005; Giuliani et al., 2005; Humphrey & Schmitz, 2002). When, for example, 'relational' value chain governance emerges, the attributes of relatively complex transactions are managed through a high level of explicit coordination between buyers and suppliers, which favors exchanges of tacit knowledge across enterprises and more enduring relationships. Alternatively, when 'modular' value chains emerge, companies can deal with these complexities by making use of technical standards and other codification mechanisms. This governance mode, in turn, relies on stronger suppliers' internal capabilities compared to relational GVCs, because direct knowledge exchanges and assistance from buyers tend to become less common (a detailed discussion of GVC governance is provided in Section 2).

Our central hypothesis in this paper is that 'relational' and 'modular' value chains are the governance modes most conducive to innovation for suppliers of intermediate products. This conjecture relies on the notion that these value chains, by combining higher levels of inter-firm coordination and supplier capability, foster richer flows of information across firms, and create an especially favorable environment for innovation. Our a priori expectation is that 'relational' value chains in particular will be strongly and positively correlated with supplier innovation due to a higher need for coordination and transfer of tacit knowledge between buyers and suppliers in these relationships. This expectation is supported by most of the GVC literature, which tends to consider that relational value chains provide the ideal environment for upgrading (Giuliani et al., 2005; Humphrey & Schmitz, 2002; Pietrobelli, 2008; Pietrobelli & Rabellotti, 2007).

The first key challenge in tackling this research question relates to the unobservability of governance modes. To overcome this issue, we take advantage of the connection predicted in the GVC theory between the level of explicit coordination in value chains and suppliers' internal technological capabilities to retrieve proxies for governance modes. In particular, we use unique measures provided by the MET (*Monitoraggio, Economia e Territorio*) survey in the 2009-to-2015 waves to obtain credible proxies of both variables. We capture suppliers' internal technological capabilities with the *share of employees devoted to planning, research, and innovation* in

[2] The term 'governance' refers to the "authority and power relationships that determine how financial, material, and human resources are allocated and flow within a chain" (Gereffi, 2019).

the total workforce of the firm. This measure, in addition to R&D personnel, also includes a broader set of skills, resources, and routines that are necessary for a company to produce, absorb, and make use of external knowledge. As demonstrated by the literature on technological capabilities (Bell & Pavitt, 1993; Lall, 1992; Teece & Pisano, 1994; Teece et al., 1997), these broader capabilities represent a key part of the skillset needed for innovation. We employ firms' *share of sales from subcontracting* over total sales – i.e., products that are made-to-order based on the specifications of a client – to measure the level of explicit coordination in the value chain. Indeed, we expect suppliers of intermediates selling products made under the specifications of their customers to coordinate more closely with such buyers. They also rely on their customers for advanced business capabilities (e.g., design, marketing, supply, and distribution) and tend to have fewer commercial alternatives.

We argue that our taxonomy for governance regimes makes an important contribution to the existing literature. The idea of governance itself is hardly considered in quantitative studies, with few exceptions (e.g., Agostino et al., 2020; Brancati et al., 2017; Pietrobelli & Saliola, 2007). Most GVC studies using firm-level survey data tend to consider only a firm's position in value chains, combined with some notion of participation depth through exports, imports, foreign direct investments, or self-declared engagement in networks (Accetturo & Giunta, 2018; Agostino et al., 2015 and 2016; Giovannetti et al., 2015). Our paper takes a step further by developing a classification of governance modes that is applicable in a quantitative setting.

Research on Global Value Chain (GVC) governance has primarily centered on upgrading. Our paper takes a distinct approach by highlighting product and process innovations as the central focus. Although frequently used interchangeably, innovation and upgrading are not synonyms, and there is a growing recognition in the literature that the interplay between GVC participation and innovation demands dedicated attention (Pietrobelli & Rabellotti, 2007 and 2011; Morrison et al., 2008; De Marchi et al., 2018). This emphasis is further supported by the large empirical literature assessing the impact of trade on innovation at the firm-level (Damijan and Kostevc, 2015; Friesenbichler & Reinstaller, 2023; Tomàs-Porres et al., 2023). In this context, our paper offers fresh insights into the pivotal relationship between GVCs governance and suppliers' innovation.

Our evidence supports the initial hypothesis that value chain governance regimes that combine higher explicit coordination and sufficient supplier capability are associated with suppliers' stronger innovation performance. However, unlike most of the related literature and against our initial expectations, we find that modular governance modes – and not relational ones – tend to be associated with the best conditions for innovation. We explain this central result as indicative that power asymmetries and dependence on few buyers in the value chain may limit innovation more than usually assumed. At the same time, we clearly show that market-based relationships tend to be problematic for firms with low capabilities, as they combine poor internal and external sources of learning. We need to remind here that our analysis is correlational and should not be interpreted in causal terms, although we take measures to assuage some endogeneity concerns.

The remainder of the paper is organized as follows. Section 2 reviews the theoretical background and builds the hypotheses of the paper. In Section 3, we present

the dataset and the main variables employed. In Section 4 we outline the empirical methodology, whose results are extensively discussed in Section 5. Finally, Section 6 concludes the paper, reviews possible policy implications, and discusses some limitations of our analysis.

2 Theoretical background

2.1 GVC Governance and its measurement

Suppliers have been the main focus of the GVC approach since its very outset (Gereffi et al., 2005; Giuliani et al., 2005; Humphrey & Schmitz, 2002). The emphasis of this literature on the existence of hierarchical relationships in value chains led to the identification of a rich taxonomy of governance modes that regulate and coordinate production. Following the literature on transaction costs (Antràs & Helpman, 2004; Coase 1937; Williamson, 1985), the complexity of transactions is recognized as a major factor explaining the transition from arm's-length market relationships to the full integration of the production tasks within the boundaries of firms. In between these two extremes, however, the GVC literature identifies several possible governance modes characterized by different levels of explicit coordination and power asymmetry: *captive*, *relational,* and *modular* value chains.

The first two, captive and relational governance modes, will typically emerge when the products being transacted are not standardized, making relationships too complex to be handled through arm's-length relationships. In captive value chains, suppliers are confined to narrow tasks (such as simple assembly) and depend on their buyers for more sophisticated complementary activities (e.g., design, logistics, and innovation) due to their low capabilities. Relational value chains, in turn, can emerge when suppliers are more capable. In these value chains, a high level of buyer engagement can transfer tacit and explicit knowledge to suppliers in transactions that may be mutually beneficial thanks to complementarities in buyers' and sellers' competencies. Although the assistance from buyers may help suppliers in captive value chains, this process may be hampered by their low level of competence, as well as their financial and technological dependence on their buyers. As a result, most of the GVC literature tends to consider relational governance as the ideal environment for upgrading (Giuliani et al., 2005; Humphrey & Schmitz, 2002; Pietrobelli, 2008; Pietrobelli & Rabellotti, 2007).

Modular value chains are somewhat in between, when transactional complexity can be codified – for example, through standards and product specifications – and suppliers are capable enough to require lower monitoring and control by the buyers. Because relationship-specific investments and explicit coordination remain low, switching costs are negligible and firms operate in an environment similar to market-based transactions. Modular value chains are still considered conducive to learning and spillovers due to the high content of non-price information flowing across firms, and because of the pressure exerted by buyers in terms of quality, technology, and innovation (Pietrobelli and Rabellotti, 2011). However, suppliers must still develop higher capabilities without buyers' assistance.

This framework initially spawned a prolific literature of very detailed case studies[3] and, more recently, growing empirical research at the firm level. Despite the difficulties in identifying governance regimes in traditional micro datasets, there is widespread evidence that suppliers tend to underperform compared to final goods producers. Such effects seem to be characterized by a significant degree of heterogeneity that depends largely on the characteristics of the suppliers (Accetturo & Giunta, 2018; Agostino et al., 2016; Veugelers et al., 2013). In fact, performance disadvantages were found to be reduced or completely dissolved for more capable firms that engage in innovation and exporting. Agostino et al. (2020) and Brancati et al. (2017) point out the role of *relational* GVCs as superior conduits for supplier learning, while Pietrobelli and Saliola (2007) show that higher involvement between buyers and suppliers in design and R&D is associated with suppliers' better performance in Thailand.

These three latter studies are of particular interest because they provide a taxonomy of governance explicitly using firm-level surveys. Agostino et al. (2020) and Brancati et al. (2017) focus on Italian two-way traders and exporters of intermediates to classify GVC participants, relying on participation in networks and involvement in product design. Pietrobelli and Saliola (2007), in turn, rely on a rich set of variables on interfirm relationships to classify governance modes according to the type of buyer (multinational, domestic, or exporter) and the level of its involvement in aspects such as the specification of the products sold by suppliers, the presence of technical standards, joint R&D, and technical assistance. Although our dataset does not provide the same information about specific relationships, we rely on products made according to buyer specifications as an indicator of engagement between buyers and suppliers, while simultaneously accounting for the role of supplier capability to build a taxonomy of governance regimes.

2.2 GVC Governance, upgrading, and innovation

Earlier studies in the GVC governance literature tended to use innovation and upgrading interchangeably. As pointed out by Morrison et al. (2008), these studies frequently understood upgrading as both a synonym and a result of an innovation process, although the innovation process itself was "never investigated directly in the literature" (Morrison et al., 2008, p. 45). This approach was grounded on the large overlap between innovation and upgrading – usually understood as the capacity to make better products, produce more efficiently, or move into technologically more sophisticated activities (Kaplinsky, 2000; Giuliani et al., 2005).

More recently, the GVC literature is increasingly acknowledging that the interplay between GVC participation and innovation demands dedicated attention (De Marchi et al., 2018; Morrison et al., 2008; Pietrobelli & Rabellotti, 2011). This emphasis arises from at least two crucial aspects: first, innovation and upgrading can both occur independently – and the conditions under which innovations will

[3] The Global Value Chains Initiative (https://globalvaluechains.org/) compiles an extensive list of case studies related to GVCs.

catalyze upgrading remain incompletely understood (Ambos et al., 2021); and second, upgrading typically stems from innovation processes, but the relationship between the latter and GVC linkages remains understudied (De Marchi et al., 2018; Morrison et al., 2008).

Many qualitative studies have delved into the relationship between GVC governance regimes and innovation by suppliers. De Marchi et al. (2018) use cluster analysis to assess the relationship between innovation patterns and GVC governance in a broad sample of the qualitative literature. The authors find evidence of a wide variety of innovation patterns, including new-to-the-world innovations in developing countries supported by value chain relationships. Like elsewhere in the GVC literature, however, there is a significant gap regarding quantitative studies at the firm level. A notable exception is Brancati et al. (2017), that study the role of innovation and R&D as upgrading channels for firms inserted in GVCs. The authors find evidence that relational value chains have a positive effect on the likelihood of both innovation and R&D by firms.

2.3 Hypotheses: Classification of governance regimes and innovation

The literature recognizes three main determinants of value chain governance regimes: (i) the complexity of transactions, (ii) the extent to which complexity can be mitigated by codifiability and (iii) the capability of suppliers. The combination of such attributes results in governance types that can be mapped out into degrees of explicit coordination and power asymmetry that are strictly increasing across modular, relational, and captive value chains (Gereffi et al., 2005). At the opposite extremes of this classification, market and hierarchical GVCs have, respectively, the lowest and highest levels of coordination and power asymmetry.

This hierarchy of coordination levels is crucial for our classification of governance regimes because the level of granularity of information necessary to measure all three determinants is hardly available in most firm-level surveys. The MET dataset makes relevant steps forward in several directions but capturing the complexity and codifiability of transactions is still not directly possible. To overcome this drawback, we propose a classification of governance regimes that focuses on the degree of coordination in the value chain and suppliers' technological capabilities. As mentioned above, the former variable provides a strong indication of the prevailing governance regime for suppliers, while the latter complements it by allowing a closer correspondence with the governance taxonomy proposed by Gereffi et al (2005).

To proxy for capabilities, we take advantage of the share of employees devoted to planning, research, and innovation activities (*PRI*). This variable includes R&D personnel plus a broader set of functions and skills within the firm related to the generation and management of technological change, representing a key part of the skillset necessary for innovation to reflect technical capabilities (Bell & Pavitt, 1993; Lall, 1992). Moreover, it is also relevant for sectors where simple measures of R&D are knowingly regarded as poor proxies for firm capabilities.

We employ the share of sales-to-order in the total revenues of the firm (*Stor*) as a proxy for the degree of coordination in the value chain. Commercial relationships of

this kind are described in the survey as "the production and sale of products made-to-order under specifications provided by the buyer", which entail a significant level of explicit coordination, signaling a clear departure from simple arm's-length transactions based only on prices and quantities. It is worth noting that this variable is also likely to capture the level of power asymmetry in the chain, which tends to be highly correlated with coordination. Importantly, a strong level of control by the buyer (e.g., through strict contractual arrangements defining sanctions in case of a breach) may impose constraints on a supplier's possibilities to innovate and upgrade (Alcacer & Oxley, 2013).

Further information on the construction of these two variables is provided in the coming section. Table 1 reports our taxonomy for governance regimes based on our firm-level evidence. We rely on *Stor* to position firms along the 'degrees of explicit coordination' axis and combine it with the capability level proxied by *PRI* to pin down a broad correspondence with Gereffi et al. (2005) original classification. The advantage of our method is that it can be employed beyond case studies at an economy-wide scale, and that it represents a detailed approximation of the original theory of GVC governance with its important insights.

Because of the high skewness of *PRI* and *Stor* (nil for 60% and 55% of the sample, respectively), we cannot rely on simple terciles for our classification. We start by defining $Stor = 0$ and $PRI = 0$ as the low regime for both variables and split the remaining observations in approximately equal numbers between the medium and high regimes.,[45] The reader may notice that the total of nine categories outnumbers the original taxonomy of Gereffi et al. (2005) explained above, but this allows us to explore higher degrees of heterogeneity along both dimensions, with some important insights.[6] Notably, we explore the role of possible knowledge hold-ups. This behavior is widely documented in GVC studies when lead firms intentionally refrain from sharing core knowledge with highly capable subcontractors if they fear the use of this knowledge may be beneficial for their competitors (Alcacer & Oxley, 2013; Ambos et al., 2021; Lee et al., 2018).[7] Conversely, there is broad support for the idea that stronger internal capabilities of suppliers will facilitate the generation and

[4] Despite being sensible, our choice of cutoffs can be considered, to some extent, ad hoc. As we discuss in Section 5 (and Section A3 of the Online Appendix), we assuage concerns about the arbitrariness of our choice by testing alternative thresholds and employing threshold-regression techniques to select cutoffs in a data-driven fashion. Interestingly, our choice is very close to the thresholds that emerge from such an empirical approach.

[5] Because of specificities in the respective distributions, we end up using as a second cutoff the 74th percentile for *Stor* (since 25% of the observations are concentrated in the upper bound; i.e., $Stor = 1$) and the 79th percentile for *PRI* (which provides a more equal distribution than the 80th percentile, whose value spans up to the 84th percentile). Details on the distribution of *Stor* and *PRI* are provided in Appendix III.

[6] Later, we present results with six simplified governance modes, reducing the *PRI* classes to two subgroups, with a closer correspondence with the GVC theory. These results largely confirm the findings of the main analysis.

[7] Another complementary or alternative possible explanation is the role of technology gaps in value chain relationships. In this context, the learning possibilities connected to supplying intermediates depend on the firm's capabilities, but also on the potential for knowledge transfer of the relationship with the buyer. Suppliers with capabilities that are too high will likely acquire little knowledge from their clients and rely more on internal or other external sources of learning. This argumentation is consistent, for

Table 1 Classification of governance regimes

		Technological Capability (PRI)			Most likely correspondence w/ Gereffi et al (2005)
		Low PRI = 0	Medium 0 < PRI ≤ 0.09	High PRI > 0.09	
Explicit Coordination (Stor)	Independent Stor = 0	1 LC-IS	2 MC-IS	3 HC-IS	Market
	Flexible 0 < Stor ≤ 0.97	4 LC-FSS	5 MC-FSS	6 HC-FSS	Modular
	Specialized Stor > 0.97	7 LC-SSS	8 MC-SSS	9 HC-SSS	Captive / Relational

This table reports the construction of our taxonomy for GVC governance modes. Labels show the acronym for each group: LC, MC, and HC stand for low, medium, and high capabilities, whereas IS, FSS, and SSS stand for independent suppliers, flexible STOR Suppliers, and specialized STOR suppliers. Cut-off levels are shown under the corresponding measure employed. Authors' elaboration

use of both external and internal knowledge and innovation. Due to this complex interplay, we refrain from hypothesizing an a priori performance hierarchy between medium- and high-capability suppliers *within* similar governance types. In our view, this is ultimately an empirical question and both results are well-grounded in theory.

Nonetheless, based on this framework, we can construct other hypotheses regarding the relationship between governance regimes and innovation performance. First of all, we classify categories 1–3 as Low, Medium and High-Capability Independent Suppliers respectively (LC-IS, MC-IS, HC-IS). Firms within these groups do not produce made-to-order goods under buyer specifications and operate under conditions that are similar to a market-based governance regime (they are also less likely to engage in networks with other firms). Therefore, their transactions are mostly governed by price mechanisms, with a reduced exchange of information and knowledge from their buyers.

Notice that low-capability firms in Category 1 (LC-IS) operate in a context of reduced explicit coordination (likely involving low levels of complexity and high codifiability in transactions) and would probably not participate in international value chains because of their lower efficiency and a higher propensity for more local relationships with lower technical requirements. The presence of these firms is quite frequent in many countries and well reported in the literature (Gereffi et al., 2005, p. 87 and 101). Accordingly, given the key role of capabilities in this market setting, our first hypothesis is that the innovation premia related to supplying intermediates will be low for Category 1 firms.[8]

Footnote 7 (continued)
example, with Girma (2005), who employs threshold-regression techniques and finds higher spillovers at medium levels of absorptive capacities. For such firms, capabilities are sufficiently high to allow for learning, and at the same time not so large to imply negative or small technology gaps that may limit the transfer of new knowledge.

[8] This may be explained by these firms' difficulty of creating and absorbing knowledge, and by the low learning opportunities offered by value chain buyers.

In a symmetric way, we classify categories 4–6 as Low-, Medium-, and High-Capability Flexible sales-to-order Suppliers (LC-FSS, MC-FSS, and HC-FSS, respectively). These companies rely on intermediate levels of sales-to-order, which means that they operate flexibly, supplying products manufactured both in autonomy and according to the client's specifications. Their dependence on specific buyers is not high: on average, sales-to-order from the main buyer is around 20%, which indicates that only around 9% of their *total* revenue arises from the main subcontractor see Table 3 in Section 5.[9] Thus, despite engaging in sales-to-order relationships, these suppliers are likely to retain a high level of autonomy over their production decisions. They can therefore supply several clients while relying on coordination mechanisms that involve richer knowledge flows compared to pure market-based transactions. While low-capability firms (LC-FSS) are unlikely to benefit from such relationships, this mode of governance corresponds quite closely to Gereffi et al. (2005) modular value chains for firms with medium and high capabilities (MC-FSS and HC-FSS). Accordingly, our second hypothesis is that these firms in modular value chains will display a strong positive correlation between supplying intermediates and innovation performance.

It is worth noticing that this argument also depends on the actual complexity of transactions or codifiability through codes and standards, that we cannot observe directly. These firms (MC-FSS and HC-FSS), nonetheless, share a key trace of modularity in their operations: under these conditions, suppliers and customers can likely be linked and delinked easily from the value chain, while still exchanging large volumes of non-price information to specify the characteristics of made-to-order products and processes. This supports the notion that this mode of governance stands between arm's-length and relational value chains in terms of explicit coordination and power asymmetry between suppliers.

We classify firms in categories 7–9 as Low-, Medium-, and High-Capability Specialized STOR Suppliers (LC-SSS, MC-SSS, and HC-SSS, respectively). In such regimes, firms operate under high levels of explicit coordination (high STOR), and rely strongly on few buyers, with a dependence on the main subcontractor of about 40%.[10] This condition provides firms with the opportunity to develop high-quality linkages with their buyers, especially in the case of highly capable suppliers that can exploit complementary capabilities to develop innovations. However, at the same time, such a high dependence can represent a limiting factor if the suppliers' capabilities are low and the level of power asymmetry becomes too high. Thus, firms in the LC-SSS group are likely operating in regimes like *captive* or semi-hierarchical value chains, facing strong limitations to their innovation process. On the other hand, MC-SSS and HC-SSS are more likely to operate under *relational* governance, with bonds of mutual dependence with buyers within complex transactions and

[9] This number is obtained from the group average of variable *Dependence* resulting from the interaction between the share of the most important buyer in total sales-to-order revenues (*Stor_MB*) and *Stor*. For this group of suppliers, the average of *Stor* is around 44% (see Table 4).

[10] A similar level of total revenue is obtained from the main sales-to-order buyer (*Dep* = 40%) since *Stor* is close to 100% for this group of firms.

two-way knowledge flows. While the literature is ambiguous regarding the extent to which captive value chains can promote innovation, it clearly supports our third and final hypothesis, i.e., that firms in *relational* governance value chains will exhibit the strongest correlation between supplying intermediates and innovation performance.

3 Data and main variables

Most of our data comes from the MET (*Monitoraggio, Economia e Territorio*) database on Italian firms. The survey contains information on research activities and product and process innovation, as well as on firms' export, workforce distribution by task, types of products sold (final goods, intermediates, and services) and earnings originated from sales-to-order activities (i.e., subcontracting). These unique characteristics differentiate this dataset significantly from common innovation surveys. We make use of four waves of the survey – 2009, 2011, 2013, and 2015 – and match them with official balance-sheet information provided by CRIF-Cribis D&B.[11] We focus on manufacturing sectors, and the final sample ranges from 8,000 to 28,000, depending on model specifications (Table 6 in Appendix). Because we impose constraints on the availability of balance-sheet data (not available for unincorporated firms, *società di persone*), our restricted sample contains firms that are on average larger, older, and more internationalized (Table 2). Although our approach controls for unobserved and observed firm heterogeneity, including size, this comparison suggests that our results are more representative of the relatively larger companies in the overall Italian population (Table 2).[12]

As noted above, *Stor* and *PRI* refer, respectively, to the share of sales-to-order in the total earnings of the firm and to the percentage of employees devoted to planning, research, design, engineering and innovation activities. The latter variable is self-declared by respondents. We find indications that higher levels of the variable *Stor* are indeed associated with increasing degrees of both coordination and power asymmetry in value chains by comparing it with another variable present in the MET survey, i.e., the share of the most important buyer in total sales-to-order revenues (*Stor_MB*). The latter is a straightforward indicator of the level of commercial dependence of the supplier on its main made-to-order buyer.

[11] Details on the sampling scheme of the MET survey are provided in Section A1 of the Online Appendix. Despite two additional waves are available (2017 and 2019) we restrict our analysis to a reduced time span due to data availability about the task distribution of the workforce (which we employ in the construction of our governance modes and whose question was removed from the survey in 2017).

[12] Notice that this constraint does not induce sizable distortions for our research questions as excluded firms, typically micro-sized, are the least likely to participate in a GVC. Moreover, to the extent that smaller companies have the largest potential gains from value chain participation, if a bias exists this is allegedly an attenuation bias for our results on the positive impulse of GVCs on firms' innovativeness. Nevertheless, we explicitly control for firms' size and fixed effects (purging any characteristic that is stable over time) which should account for most of this bias. Finally, there is no clear indication that such a sample selection shapes our findings on the heterogeneity of firms' innovativeness and performance to the specific characteristics of the governance mode.

Table 2 Descriptive statistics

	Total Sample				Restricted Sample			
	N	Avg	Stdev	p50	N	Avg	Stdev	p50
PRI	27,906	0.047	0.095	0.00	24,579	0.048	0.095	0.00
Stor	51,060	0.319	0.463	0.00	24,579	0.34	0.438	0.00
Sup	50,691	0.21	0.367	0.00	24,579	0.205	0.372	0.00
Dep	32,840	0.14	0.27	0.00	14,895	0.13	0.24	0.00
MB_High	32,835	0.08	0.27	0.00	14,895	0.08	0.26	0.00
Prod	51,060	0.3	0.46	0.00	24,579	0.3	0.46	0.00
Proc	51,060	0.24	0.43	0.00	24,579	0.23	0.42	0.00
Rad	51,055	0.28	0.45	0.00	24,579	0.28	0.45	0.00
Imit	51,055	0.26	0.44	0.00	24,579	0.25	0.44	0.00
Exporter	51,060	0.49	0.5	0.00	24,579	0.58	0.49	1.00
Ln Innov Rev	44,821	3.71	6.33	0.00	23,375	3.71	6.46	0.00
Size	51,060	2.97	1.31	2.83	24,579	3.49	1.14	3.30
Age	50,675	3	0.7	3.09	24,579	3.11	0.65	3.22
Vertical integration	43,900	0.3	0.26	0.29	23,282	0.3	0.22	0.29
Group	51,060	0.17	0.38	0.00	24,579	0.21	0.41	0.00

We present the number of observations (N), averages (Avg), standard deviations (Stdev), and medians (p50) for the entire set of companies available in the MET survey (left panel) and for the restricted sample used throughout this paper (right panel)

In the context of customized transactions, sales that are more concentrated on one buyer will tend to be related to higher levels of explicit coordination, higher relationship-specific investments, and larger switching costs. Crucially, the correlation between this variable and the share of sales to order in total revenues (*Stor*) is strong and positive (0.62), which ultimately results in a compounded effect upon the overall dependence of suppliers on a single buyer.[13] Unfortunately, information about the main buyer (*Stor_MB*) is only available for the last two waves of the MET survey (2013 and 2015). Thus, using this variable instead of *Stor* would greatly reduce our sample size, as well as our ability to control for unobserved firm characteristics. For this reason, our main specification relies on the more general measure of subcontracting (*Stor*), that allows us to track governance regimes over a longer time span. Nevertheless, we still employ *Stor_MB* in our robustness checks (Section 5.2) on the consistency of our results.[14]

[13] The interaction between *Stor* and *Stor_MB* identifies the share of the most important sale to order buyer in a firm's *total* sales. We employ this measure ("dependence", in our notation) in Section 5.2, where we present our robustness tests.

[14] Firms engaging in sales-to-order activities are also 56%-more likely to participate in networks, defined as "significant and ongoing relationships with other companies, entities, or institutions", especially networks for commercial purposes. Many of these networks are likely to involve closely-coordinated relationships.

The MET survey also allows for a straightforward identification of suppliers, as it asks firms about the share of revenues from the sales of semi-finished (intermediate) goods to other firms (*Sup*). Importantly, this measure allows us not only to identify the effect of being a supplier or not, but also to quantify how intensively firms engage in value chains as suppliers (as some of these firms may also sell final goods outside the value chain).

The central focus of our empirical analysis is on *innovation*, which we measure across different levels and types. In the MET survey, we use product (*Prod*) and process (*Proc*) innovations as our main indicators, but we also distinguish between innovations that are new to the market (*Rad*) and only new to the firm (*Imit*), i.e. radical vs. imitative innovations, respectively. In additional specifications, we broaden our analysis to test for the influence of governance upon the share of sales from product innovations (*Ln Innov Rev* in our notation), which is one of the possible effects of innovations.

Finally, in most regressions, we include structural controls for the log and squared log of firm age and number of employees,[15] as well as for the lagged log of vertical integration (value-added-to-revenues ratio) and for the participation of the company in a corporate group, which are frequently seen as important strategic and financial facilitators of innovation (Adelman, 1955; Armour & Teece, 1980).

4 Empirical strategy

The baseline specification of our empirical analysis is a standard reduced-form model for the introduction of innovations, augmented with a vector of dummies for our GVC governance modes. Because firms participate in value chains to a different extent, we allow the effect of governance regimes to be mediated by the degree of involvement in a GVC, as captured by the share of sales coming from intermediate goods.[16] Our baseline model reads as follows:

$$Inov_i = \alpha_0 + \boldsymbol{\delta G_i} \times Sup_i + \alpha_1 \mathrm{PRI}_i + \alpha_2 Stor_i + \mathbf{\beta Z_i} + \alpha_i + \nu_t + \mu_i \qquad (1)$$

wherein $Inov_t$ is the binary outcome of the innovation process, $\mathbf{G_i}$ is the vector of nine dummy variables reflecting our classification of governance regimes, and Sup_i is the share of firms' turnover realized from sales of intermediate/semi-finished products to other firms, allegedly capturing the reliance on value chains. We also allow for a direct impact of PRI_i (share of employees in design, research, and innovation) and $Stor_i$ (share of turnover from sales-to-order activities) to control for effects that are directly linked to such characteristics and not related to value chain participation. Finally, $\mathbf{Z_i}$ is the vector of time-varying firm-level structural controls (degree of vertical integration, dummy for corporate group belonging, log of firms' age and size, both in levels and squared to allow for diminishing returns), while α_i

[15] The squared terms account for diminishing returns in firms' experience and size, respectively (Huergo & Jaumandreu, 2004; Raymond et al., 2015).

[16] Clearly, firms producing final goods may be involved in value chains as well, or may also develop supply relationships with other firms by selling custom-made capital goods. However, we cannot make any informed speculation about governance for them as we have no further information in our dataset.

and ν_t are, respectively, firm and time fixed effects which perfectly account for persistent unobserved heterogeneity (all firm-specific factors that do not vary over time) and cyclical components or common shocks (so to purge the model from the effect of the business cycle onto innovations and GVC participation).

Our research question is mainly informed by the significance and the potential heterogeneities associated with the elements in $\boldsymbol{\delta}$. Notice that, since Sup_i is a continuous interacted variable between 0 and 1, each estimate in vector $\boldsymbol{\delta}$ reflects the mediating role of governance groups upon the relationship between supplier's share of intermediate sales and their innovation performance. However, we also show that results would be confirmed if one assumes the effect of governance regimes not to depend on the intensity of engagement in sales of intermediates (i.e., excluding the interaction with Sup_i, Section 5.2).

Since $Inov_i$ is, in most cases, a dummy dependent variable, the natural model for Eq. 1 calls for a non-linear estimator of binary choices. Nonetheless, the need to control for unobserved characteristics requires firm-level fixed effects, which for such models are generally not consistent (i.e., incidental parameters problem). We adopt a double approach and estimate Eq. 1 employing both linear-probability fixed-effects models (FE-OLS; i.e., within estimator) and random-effects probit models (RE-Probit) with Mundlak correction.

The Mundlak approach consists of estimating a random-effects model augmented with the time averages of the right-hand side variables in the equation. This allows to control for the correlation between the individual effects and the regressors, thus relaxing the unrealistic orthogonality conditions of standard random effects (Wooldridge, 2010). When presenting results for such estimators, we only report average marginal effects for simplicity of interpretation. Overall, both approaches provide largely consistent results.

The simultaneity between our dependent variable and the set of regressors could also generate endogeneity. Unfortunately, finding appropriate instruments for all variables that define the governance categories we analyze is unfeasible. One way to partially reduce this drawback is to lag the right-hand side of the model, which imposes a time hierarchy and takes care of the simultaneity bias. In our case, however, imposing lags in the fixed effects model is also not feasible because it would require an excessive reduction in the sample size due to the need for balanced observations in three consecutive waves. Nonetheless, our results are broadly confirmed when we employ pooled models to allow for lagged regressors (Section 5.3). Although these approaches are helpful to a certain extent, it is important to highlight that in absence of appropriate instruments, and our results should not be interpreted as indicating causal relationships.

5 Results

5.1 Main results

Some descriptive results are presented in Table 3, where we synthesize the conditional distribution of several measures along our taxonomy for GVC governance regimes. First of all, Independent Suppliers (groups 1, 2, and 3) appear to be the most common typology as well as the subset grouping the largest companies in terms of employees. Importantly,

Table 3 Governance regimes and conditional distributions among suppliers

Category	Obs (%)	PRI (%)	Sup (%)	Stor (%)	Stor_MB (%)	Prod (%)	Proc (%)	Size
1 LC-IS	25.63	0.00	70.58	0.00	0.00	0.18	0.17	3.45
2 MC-IS	8.80	4.34	57.98	0.00	0.00	0.58	0.43	4.27
3 HC-IS	10.12	17.67	57.26	0.00	0.00	0.50	0.40	3.91
4 LC-FSS	11.28	0.00	65.79	44.63	20.75	0.21	0.23	3.20
5 MC-FSS	5.75	4.58	52.51	43.12	18.55	0.55	0.45	3.76
6 HC-FSS	6.54	17.61	52.45	45.20	21.45	0.53	0.43	3.49
7 LC-SSS	21.18	0.00	85.63	99.99	40.35	0.14	0.17	3.19
8 MC-SSS	5.27	4.43	83.47	99.95	36.01	0.36	0.41	3.67
9 HC-SSS	5.45	17.24	79.35	99.97	39.52	0.39	0.37	3.40
Overall Avg	-	4.76	69.70	42.35	17.33	0.30	0.28	3.52
Total Obs	-	7253	7,253	7,253	4,972	7,253	7,253	7,253

This table reports the distribution of suppliers across governance regimes (in column 1) and the conditional averages for each group along the main variables employed in the analysis (columns 2-to-8). The two bottom rows display the total number of observations available for each measure in the sample and the overall averages. All variables are defined in Appendix (Table 6)

such firms also tend to display the highest levels of innovativeness, together with Flexible STOR Suppliers (groups 4, 5, and 6), while Specialized STOR Suppliers (groups 7, 8, and 9) seem to be characterized by a substantially lower innovation propensity.

Such heterogeneity is likely driven by the different environments in which firms operate. While the heterogeneity in *PRI* and *Stor* across our taxonomy is achieved by construction, column 6 clearly shows the strong correlation with *Stor_MB,* whereby a higher share of turnover from made-to-order relationships is also associated with (steeply) increasing dependence on their main buyer. This evidence further reassures us about the capability of our classification to capture heterogeneous levels of explicit coordination and dependence. In our empirical exercise we explore whether behind such a heterogeneity there are some nexuses linking GVC governance regimes to the innovation performance of the firms involved (Table 3).

Table 4 presents our baseline results from random effects Mundlak probit models (average marginal effects are reported).[17] In columns 1 and 2, we focus on the introduction of new products, and we observe the very strong and significant direct effect of *PRI*, confirming a priori expectations on the role of firms' capability in absorbing and elaborating knowledge. In contrast, the effect of *Stor* is largely negative, pointing at the overall greater difficulties in the innovation process when suppliers depend on made-to-order relationships. On top of these direct effects, significant heterogeneities emerge across the different governance regimes.[18]

[17] Linear probability models have very similar results in terms of size and significance of the coefficients (see Table 9 of Appendix I).

[18] Notice that additional controls are largely insignificant because most of their effects are captured by the time-demeaning process of the Mundlak correction (i.e., the time variation is not enough to achieve significance).

Firstly, Flexible STOR Suppliers (the FSS group) show a positive and significant relationship between supplying intermediates and their innovation performance, but only if technological capabilities are at medium levels (MC-FSS). Within this group, a one-percentage-point increase in *Sup* is associated to an average marginal probability of innovating about 0.15% higher than firms that do not sell intermediates. Such an effect can be small for firms with low levels of *Sup,* but can produce a dramatic increase in the likelihood of innovation when intermediates represent the main type of goods produced (15% higher probability of innovation if *Sup* is equal to 100%).

The associated impact is by far the largest effect among all groups,[19] indicating that modular value chains would offer the most favorable environment for suppliers to innovate (Table 4). This is likely to be driven by the high level of information exchange in the context of less asymmetric value chain relationships with capable suppliers. Notice that firms' capability levels have a critical role for FSS, although not in a linear fashion. Low Capability Flexible STOR Suppliers (LC-FSS) do not appear to enjoy any innovation premium as their intensity of intermediate goods sales increases. Interestingly, the estimate for firms with high levels of capability (HC-FSS) is also largely insignificant (albeit positive). A similar pattern is also found for other governance regimes, as we will discuss later in this section.

Secondly, we confirm our first hypothesis in Section 2.3 that market-based relationships combined with low supplier capabilities (LC-IS) present the least favorable environment for innovation. Among these firms, a one-percentage-point increase in *Sup* implies a marginal *reduction* in the probability of innovating of about 0.07% compared to firms that do not sell intermediates. Such suppliers have low internal capabilities to absorb and create knowledge which, coupled with weak external learning sources, result in significantly lower innovation propensity. Notably, higher capability levels appear to offset this negative effect, as emphasized by the insignificance of MC-IS and HC-IS.

At the same time, firms in the group of Low Capability Specialized STOR Suppliers (LC-SSS), which we can associate with captive value chains, do not present significant effects of *Sup* on innovation. This pattern, together with the ones in the following columns, emphasizes how the potential benefits of explicit coordination and tacit knowledge exchange within captive relationships can be severely hindered by the lack of complementary capabilities needed to absorb such knowledge and make productive use of it.

The picture for the remaining groups is more ambiguous. Medium capability firms benefit from supplying intermediates in relational and market-based value chains (MC-SSS and MC-IS, respectively) when process innovations (columns 3 and 4) are considered but not for product innovations in columns 1 and 2. In column 3, a one-percentage-point increase in *Sup* is associated with a rise in the probability of developing a new process of 0.107% for MC-SSS suppliers and 0.074% for MC-IS suppliers. Taken together, these results suggest that the innovation intensity and scope benefits arising from such value chains tend to be more limited than in modular value chains. While these insights confirm our second hypothesis in

[19] Except for HC-FSS, we confirm that the coefficients for this category in columns (1) and (2) are significantly different from all others at the 10% level.

Table 4 Governance regimes and innovation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Model	RE-Probit	RE-Probit	RE-Probit	RE-Probit	RE-Probit	RE-Probit	OLS-FE
Dependent Variable	Prod	Prod	Proc	Proc	Rad	Imit	Ln Innov Rev
PRI	0.467***	0.447***	0.281***	0.269***	0.345***	0.329***	7.319***
	(0.059)	(0.054)	(0.052)	(0.048)	(0.056)	(0.056)	(1.030)
Stor	-0.035***	-0.032***	-0.010	-0.010	-0.019	-0.032***	-0.538***
	(0.012)	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)	(0.178)
1 LC-IS	-0.070***	-0.072***	-0.044**	-0.042**	-0.064***	-0.051**	-1.071***
	(0.021)	(0.020)	(0.021)	(0.019)	(0.022)	(0.022)	(0.280)
2 MC-IS	0.048	0.047	0.074**	0.059**	0.031	0.067**	0.489
	(0.033)	(0.030)	(0.032)	(0.029)	(0.034)	(0.033)	(0.625)
3 HC-IS	-0.010	-0.006	0.017	0.024	0.050	-0.064*	-0.221
	(0.033)	(0.031)	(0.031)	(0.030)	(0.035)	(0.034)	(0.603)
4 LC-FSS	0.023	0.028	0.052	0.061**	-0.020	0.041	-0.232
	(0.035)	(0.032)	(0.033)	(0.030)	(0.033)	(0.036)	(0.425)
5 MC-FSS	0.147***	0.137***	0.149***	0.142***	0.140***	0.154***	1.497**
	(0.043)	(0.039)	(0.045)	(0.042)	(0.047)	(0.048)	(0.722)
6 HC-FSS	0.044	0.074	0.130***	0.143***	0.075	0.170***	0.818
	(0.052)	(0.047)	(0.044)	(0.042)	(0.047)	(0.047)	(1.043)
7 LC-SSS	-0.026	-0.024	-0.007	-0.001	-0.040*	0.006	-0.241
	(0.026)	(0.023)	(0.022)	(0.020)	(0.024)	(0.024)	(0.270)
8 MC-SSS	0.024	0.022	0.107***	0.095***	0.013	0.106***	0.667
	(0.035)	(0.033)	(0.037)	(0.034)	(0.037)	(0.041)	(0.536)
9 HC-SSS	0.034	0.030	0.018	0.012	0.014	0.034	0.143
	(0.034)	(0.032)	(0.034)	(0.032)	(0.035)	(0.034)	(0.601)
Vertical integration	0.029		0.014		0.015	-0.003	0.058
	(0.030)		(0.026)		(0.029)	(0.026)	(0.312)
Age	-0.122		-0.033		0.036	-0.028	-0.759
	(0.093)		(0.091)		(0.099)	(0.092)	(1.957)
Age^2	-0.001		-0.009		-0.034	-0.015	-0.177
	(0.021)		(0.020)		(0.022)	(0.021)	(0.660)
Size	0.035		0.036		0.022	0.039	0.317
	(0.036)		(0.038)		(0.039)	(0.038)	(0.562)
Size^2	-0.000		-0.001		0.001	-0.001	0.071
	(0.005)		(0.006)		(0.006)	(0.006)	(0.097)
Group	0.027*		0.015		0.025	0.022	0.351
	(0.015)		(0.015)		(0.016)	(0.016)	(0.288)
Observations	24,579	27,697	24,579	27,697	24,579	24,579	23,375
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mundlak Correction	Yes	Yes	Yes	Yes	Yes	Yes	No
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	No

Table 4 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	No
Firm FE	No	No	No	No	No	No	Yes

Marginal effects from RE-probit models with Mundlak correction. The dependent variable varies across columns and is listed in the third row (*Prod* in columns 1–2, *Proc* in columns 3–4, *Rad* in column 5, and *Imit* in column 6). All models include year, sector (2-digit), and province (NUTS3-geographical level) fixed effects. All variables are defined in Appendix (Table 6). Robust standard errors in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1%, respectively

Section 2.3 – i.e., that modular value chains are associated with a strong positive innovation performance by suppliers – the fact these firms significantly outperform relational suppliers goes largely against traditional findings of the GVC governance literature expressed in our third hypothesis.

For highly capable suppliers there appears to be little or no benefit from acting as suppliers, especially when compared to medium-capability firms. This result seems to confirm the strong and widely recognized role of knowledge hold-ups and technology gaps in the context of value chain relationships.[20] In Section 5.2, we indirectly test this possibility by including, for each governance group, interaction terms between the share of sales to the main client (*Stor_MB*) and the intensity of intermediate supply (*Sup*). As we will argue below, high-capability firms are the only ones significantly harmed by main buyer concentration, which is compatible with these effects.

Columns 5 and 6 explore firms' degree of innovativeness by distinguishing between radical (new-to-the-market) and imitative (new-to-the-firm) innovations. The patterns that emerged so far are largely confirmed. Independent firms with low capabilities (LC-IS) show negative effects regarding their probability to innovate radically, whilst medium capability suppliers in modular value chains (MC-FSS) are the only ones to present positive and significant effects in their likelihood to introduce radical innovations. The result that supplying intermediates is generally associated with patterns of imitation and process innovations aligns with findings from the GVC literature suggesting that suppliers tend to focus on more incremental forms of innovation (Giuliani et al., 2005), likely prioritizing dimensions that complement and strengthen value chain linkages, e.g., quality, flexibility and productivity (Ambos et al., 2021).

Finally, in column 7 we look at intensive margins by exploring the relationship of innovation and value chain governance with the sales of innovative products by employing the (log) sales from innovative products (*Ln Innov Rev*) as a dependent variable. Our findings are fully in line with the patterns that emerged for extensive margins, confirming that supplying intermediates has a strong correlation with the

[20] We refer to technology gaps in footnote 11 as a complementary or alternative explanation to this result. Although our data does not allow to differentiate between these two possibilities, we consider that the role of knowledge hold-ups is more clearly supported by the qualitative GVC governance literature.

sales of innovative products for Medium Capability Flexible STOR Suppliers (MC-FSS), which is the only category for which positive significant results was found at the extensive margin for product innovations. Moreover, the results for LC-IS are also confirmed here.

5.2 Robustness I: Dependence, knowledge hold-ups, and alternative thresholds

In this subsection, we present the first set of exercises aimed at assuaging possible concerns about the robustness of our results. First, we retrieve a more straightforward proxy for firms' overall commercial dependence on their most important client. We do so by interacting *Stor* with the share of the main buyer in total sales-to-order revenues (*Stor_MB*). The resulting variable (*Dep* in our notation) is likely to be a better proxy for explicit coordination in the value chain, although it has the limitation of being available only in the 2013 and 2015 waves of the MET survey (Table 5).

Alternatively, we allow for non-linearities by interacting *Stor* with a binary variable for firms that are heavily dependent on their main buyer: we define *MB_high* so to take unitary value if *Stor_MB* is larger than 50%, which is equivalent to the 90th percentile of its distribution. This exercise allows for the identification of heterogeneities within each governance group for firms facing extreme dependence on their main buyer. In line with our previous argument, we expect more capable firms to be especially harmed by such a heavy dependence due to the influence of knowledge hold-ups (or technology gaps) hindering the learning potential of the relationship. In contrast, lower-capability firms should benefit from the relational proximity allowed by the higher coordination levels with their buyers.

In columns 1 to 4 we present the main results employing a more direct proxy for dependence (*Dep*). The essential difference compared to Table 4 regards the group LC-SSS (captive suppliers), which is found to have a positive and significant impact on product and process innovations. As for the other effects, our findings appear to be largely confirm previous estimates. Firstly, firms in groups MC-FSS and HC-FSS have, in all cases, better innovation performances. Secondly, LC-IS firms present strongly negative correlations in all columns. Results for radical and imitative innovations are also in line with those of Table 4. Once again, governance regimes with medium coordination and power asymmetry, combined with intermediate or high capability levels, appear to favor suppliers' innovation. In contrast, low-capability suppliers in market-based value chains tend to be less innovative with increasing intensities of intermediates supply.

In columns 5 and 6 we interact supplier intensity for each governance group with MB_high_{it}.[21] Interestingly, high-capability STOR suppliers, both flexible (HC-FSS) and specialized (HC-SSS), present strong negative and significant estimates in most cases. HC-SSS firms with a dependence on their main STOR buyer above 50% face a 0.28% lower probability of introducing product innovations for each one-percentage-point increase in the share of sales from intermediates (as compared to firms in the same group but with lower levels of dependence). The same effect is estimated at -0.54% for

[21] Notice that interactions for Independent Suppliers cannot be estimated since such firms have, by definition, nil sales-to-order and therefore no dependence on any buyer.

Table 5 Dependence on the main buyer and alternative thresholds

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model	FE-OLS	FE-OLS	FE-OLS	FE-OLS	FE-OLS	FE-OLS	FE-OLS	FE-OLS
Dependent Variable	Prod	Proc	Rad	Imit	Prod	Proc	Prod	Proc
1 LC-IS	-0.131***	-0.107***	-0.166***	-0.126***	-0.117***	-0.124***	-0.067***	-0.042**
	(0.040)	(0.040)	(0.041)	(0.040)	(0.043)	(0.046)	(0.018)	(0.019)
2 MC-IS	0.096	0.048	0.052	0.095	0.038	0.081	0.051	0.083**
	(0.067)	(0.068)	(0.070)	(0.066)	(0.065)	(0.067)	(0.033)	(0.033)
3 HC-IS	-0.067	0.127	0.099	-0.100	-0.014	0.036	-0.064	-0.007
	(0.075)	(0.083)	(0.077)	(0.076)	(0.118)	(0.120)	(0.050)	(0.049)
4 LC-FSS	-0.026	-0.115*	-0.069	-0.088	0.073	-0.002	0.017	0.053
	(0.060)	(0.059)	(0.062)	(0.064)	(0.069)	(0.078)	(0.032)	(0.035)
5 MC-FSS	0.201***	0.127	0.041	0.194**	0.090**	0.217**	0.142***	0.209***
	(0.076)	(0.093)	(0.092)	(0.090)	(0.084)	(0.092)	(0.047)	(0.048)
6 HC-FSS	0.045	0.174**	0.115	0.125	0.056	0.257*	0.036	0.099
	(0.084)	(0.085)	(0.081)	(0.080)	(0.137)	(0.144)	(0.087)	(0.086)
7 LC-SSS	0.090*	0.100**	0.048	0.071	-0.034	-0.026	-0.017	-0.008
	(0.049)	(0.048)	(0.049)	(0.044)	(0.050)	(0.045)	(0.020)	(0.020)
8 MC-SSS	-0.021	0.131	-0.022	0.050	0.088	0.156**	0.066**	0.091**
	(0.064)	(0.085)	(0.069)	(0.076)	(0.055)	(0.071)	(0.030)	(0.037)
9 HC-SSS	0.054	0.116	0.023	0.075	-0.007	0.073	-0.117**	0.002
	(0.074)	(0.085)	(0.083)	(0.073)	(0.120)	(0.114)	(0.051)	(0.062)
4 LC-FSSxMB_High					-0.119	0.049		
					(0.148)	(0.133)		
5 MC-FSSxMB_High					0.067	0.285		
					(0.225)	(0.206)		
6 HC-FSSxMB_High					-0.535*	-0.966***		
					(0.315)	(0.302)		

Table 5 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
7 LC-SSSxMB_High					0.075	0.108		
					(0.083)	(0.081)		
8 MC-SSSxMB_High					-0.106	-0.158		
					(0.099)	(0.111)		
9 HC-SSSxMB_High					-0.277*	-0.127		
					(0.168)	(0.199)		
Observations	16,664	16,664	16,664	16,664	16,664	16,664	24,579	24,579
Adj. R-squared	0.089	0.057	0.051	0.054	0.091	0.061	0.064	0.045
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Within estimator (linear probability model) with firm and year fixed effects. The dependent variable varies across columns and is listed in the third row (*Prod* in columns 1, 5, and 7; *Proc* in columns 2, 6, and 8; *Rad* in column 3; *Imit* in column 4). We control for *PRI* in columns 1-to-8, *Dep* in columns 1-to-4, and *Stor* in columns 5-to-8. In columns 1-to-4, the cutoffs used for the new variable *Dep* are 0 and 0.13, while for *PRI* are 0.04 and 0.10. These are different to Table 4 to maintain the same percentile division in the context of smaller samples, given variable *Dep* is not available for all years. In columns 7 and 8 we employ the thresholds obtained from threshold-regression techniques outlined in Section A3 of the Online Appendix. Additional controls follow the specification in Table 4. All variables are defined in Appendix (Table 6). Robust standard errors in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

MC-FSS suppliers' probability to innovate in products and -0.98% to innovate in processes. The remaining interactions are not significant, indicating that medium- and low-capability firms are not affected to the same extent by increasing levels of power asymmetry in the value chain.[22] Overall, this set of results confirms that extreme dependence on buyers tends to be especially harmful for highly capable firms.

Finally, in the last two columns, we test for alternative thresholds by employing a data-driven approach to recover the cutoffs employed in our governance classification. The use of threshold-regression models (Section A3 of the Online Appendix) assuages concerns about the arbitrariness of our choice and provides results that are largely consistent with the ones discussed; the only noticeable difference being the negative effects for HC-SSS firms in column 7.[23]

5.3 Robustness II: Simultaneity, simplified governance, and alternative governance variables

In this subsection, we present our final set of robustness tests aimed at dealing with identification issues and simplifying our taxonomy of GVC governance modes. First, we explore the simultaneity bias by employing lagged regressors on the right-hand side of Eq. 1. While this does not allow for the inclusion of firm fixed effects due to the loss of a year in the sample, we performed a pooled estimation augmented with a rich set of specific fixed effects controlling for the 2-digit sector and NUTS2-region (together with time fixed effects already in the specification). Naturally, this approach is not enough to correct for other sources of endogeneity, notably the possible self-selection of innovative firms into specific governance groups and, therefore, does not ensure that our regressors are fully exogenous as would an instrumental variables design, if available. Nonetheless, our estimates are remarkably consistent and virtually insensitive to this change in the estimating approach, with the only noticeable difference being a stronger effect for Medium-Capability Independent Suppliers (MC-IS). Such results are hardly affected by changes in the set of controls.

Next, we employ a simplified governance classification by merging medium- and high-capability categories within each group, which results in a total of six classes of governance. Clearly, the results are very similar to the ones discussed above, but they have the advantage of providing a slightly clearer correspondence with the governance modes of Gereffi et al. (2005). Overall, we confirm the better performance of modular suppliers (MC-FSS/HC) as well as the sizable underperformance of low-capability independent suppliers (LC-IS). Relational and market-based suppliers (MC-SSS/HC and MC-IS/HC) present positive effects in a few cases, with a slight edge for relational value chains, whereas captive suppliers (LC-SSS) present non-significant or negative effects.

[22] If we reduce the *MB_high* cutoff from 50 to 35%; i.e., classifying lower buyer concentration levels as high, we find qualitatively similar, although weaker coefficients.

[23] The only difference is in the cutoff between medium and high capability firms, which is higher here, at the 88th percentile.

As a final exercise, we either replace *Stor* with a binary variable for suppliers or present results for the subsample of suppliers only. Once again, our results are highly consistent, despite the heterogeneities in the coefficients are somewhat reduced. Again, the estimates for modular suppliers remain consistently above the ones for the other categories. All these results can be found in Section A2 of the Online Appendix.

6 Discussion and conclusion

Extant literature has largely advocated the critical role of governance regimes in affecting suppliers' innovation and upgrading in GVCs (Gereffi et al., 2005; Pietrobelli & Rabellotti, 2007 and 2011). Value chain leaders and buyers may sometimes promote and other times hinder learning, innovation, and upgrading along a GVC. Thus, several studies emphasize how leaders frequently prefer to confine their suppliers to simpler activities characterized by lower value-added, while retaining for themselves the more strategic and profitable positions in the value chain. However, in many instances, GVC integration may also offer remarkable opportunities for suppliers' learning and innovation. In all these circumstances, suppliers' capabilities are crucial, as they severely affect the strategies and actions of the leaders – e.g., more capable suppliers tend to be tasked with higher-value activities – as well as the possibilities to break through to superior tasks in the same, or possibly in another, value chain (Morrison et al., 2008).

These important insights mostly originate from a vast literature of GVC case studies, which have not yet been fully integrated into the framework of the empirical firm-level economic literature. In this paper, we contribute to this strand of research by making use of unique variables available in the MET survey to build a taxonomy of governance modes and test the influence of value chain governance on suppliers' innovation performance. One of the contributions of our paper is a classification of governance modes that is applicable in a quantitative setting.

Our results suggest that modular governance is associated more strongly with suppliers' innovations. Under such governance conditions, suppliers with medium or high capabilities deal with large inflows of non-price information from clients through sales-to-order transactions, while at the same time retaining a significant level of autonomy relative to their buyers. These results for modular value chains go partially against the traditional findings of the GVC literature, which tend to indicate relational forms as the most favorable environment for suppliers to learn and innovate. We indeed observe positive and significant correlations between GVC integration and innovation also in relational value chains, but these effects appear to be smaller.

Consistently with the predictions of the GVC approach, market-based relationships are found to be problematic for the innovativeness of firms with low capabilities, where scarce internal sources of learning are combined with poor external sources. For this group, we document consistently negative correlations between supplying intermediates and firms' innovation. At the same time, captive suppliers present almost always insignificant coefficients, suggesting that they obtain no innovation benefit from value chain participation.

Finally, we show that, while the direct effect of firms' internal capacity compounds the important positive influence of governance on suppliers' innovation, the largest and most consistent results are for suppliers with medium rather than very high levels of capabilities. This is an aspect frequently ignored by the GVC literature: highly capable firms often will not learn from their buyers. We regard this as an indication of the role of knowledge hold-ups in value chain relationships, and how these may limit suppliers' learning and innovation. This is further confirmed by robustness tests showing that highly capable firms suffer the most from high levels of dependence on their suppliers.

Our results bear some relevant policy insights. We lend support to value chain policies that attempt to promote engagement, coordination, and knowledge transfer between firms, including policies focused on promoting spillovers from foreign direct investments. This potential, however, does not appear to be fully realized when firms do not preserve some strategic independence and the capacity to relate independently with many clients. In this context, the promotion of firms' market expansion and diversification appears to be a promising area for policy action, together with the strengthening of suppliers' technological capabilities (Pietrobelli et al., 2021). Finally, although our study did not look at national and regional characteristics and the innovation systems in place, these features are expected to play an important role in the facilitation of knowledge exchanges between companies and in supporting the development of capabilities. Therefore, they are also likely to influence the relationship between the governance of the value chain and suppliers' innovation and learning.

Lastly, it is worth warning again the reader that our framework does not pretend to identify causality nexuses and, as such, results should be taken with a grain of salt. Nevertheless, we trust this work may help advance a promising area for future empirical firm-level GVC studies.

Appendix: Variable definition

Table 6 Definition of the main variables

Name	Definition	Type
Sup	Share of sales from intermediates in total revenues	Bounded: (0–1)
Stor	Share of sales-to-order in total revenues	Bounded: (0–1)
Stor_MB	Share of sales-to-order from the main buyer	Bounded: (0–1)
MB_high	High dependence on the main buyer (Stor_MB > 50%)	Binary
PRI	Share of employees devoted to planning, research, and innovation	Bounded: (0–1)
Prod	Introduction of product innovation	Binary
Proc	Introduction of process innovation	Binary
Rad	Introduction of radical innovation (new to the market)	Binary
Imit	Introduction of imitative innovation (new to the firm)	Binary
Ln Innov Rev	Log of 1 + revenues from product innovations	Continuous
Age	Log of 1 + age	Continuous
Size	Log of 1 + employees	Continuous
Vertical Integration	Log of value-added-to-sales ratio	Continuous
Group	Corporate group belonging	Binary

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