Global Value Chains, Innovation, and Performance: Firm-Level Evidence from the Great Recession[☆]

Emanuele Brancati[a,b,*], Raffaele Brancati[b], Andrea Maresca[b]

[a] *Department of Economics and Finance, LUISS Guido Carli University, viale Romania 32, 00197 Rome, Italy*
[b] *MET, via Sabotino 2A, 00195 Rome, Italy*

Abstract

This paper takes advantage of a newly-available survey to analyze the behavior of Global Value Chains (GVCs) in the aftermath of the Great Recession. The analysis exploits a rich availability of information to design a comprehensive taxonomy of GVC participation modes and explore their impact on firms' innovativeness and performance. Our findings highlight relevant heterogeneities in how GVC participants fared the crisis. While high-skill *relational* suppliers display a significant propensity to engage in innovative activities and R&D projects, other modes of GVC participation have no premium compared to domestic companies. This heterogeneity is also reflected in differential productivity and sales growth. Compared to the pre-crisis trends, we document a severe demand shock for low-skill and subordinated firms, while relational GVCs appear to be somewhat sheltered from the effects of the crisis.

JEL classification: D22, F61, O30.
Keywords: Global Value Chains, Innovation, R&D, Performance, Great Recession.

[☆]We wish to thank the editor, Stephen Yeaple, and two anonymous referees for extremely helpful comments. We also thank Andrej Angelovski, Pierluigi Balduzzi, Pierpaolo Benigno, Davide Castellani, Lilian Giardino-Karlinger, Paolo Giordani, Anna Giunta, Saul Lach, Carlo Pietrobelli, Thomas Rivera, Manuel Romagnoli, Fabio Schiantarelli, Timothy Sturgeon, Giovanna Vallanti, Antonello Zanfei, as well as seminar participants at Accademia dei Lincei, University of Ancona, University of Rome La Sapienza, and University of Venice Ca' Foscari for their insightful suggestions. All errors and opinions expressed in this paper are, of course, our own.

[*]Corresponding author
Email addresses: ebrancati@luiss.it (Emanuele Brancati), r.brancati@met-economia.it (Raffaele Brancati), a.maresca@met-economia.it (Andrea Maresca)

October 19, 2015

1. Introduction

The nature of international trade has significantly changed over the past few decades. Globalization, the advent of IT, and the reduction in transportation costs have pushed firms to reorganize their activities with frequent strategies of outsourcing and off-shoring. As a result, the production of final goods has been increasingly fragmented into a large number of sequential stages coordinated in Global Value Chains (hereinafter GVCs).[1]

Whether a firms' involvement in a global production process fosters innovativeness and performance has critical implications for economic growth. Answering this question though may not be trivial in recent times of crisis. On the one hand, the literature on GVCs has emphasized the role of vertical specialization and inter-firm relationships in amplifying knowledge exchanges and enhancing productivity. On the other, latest studies on the financial crisis highlighted some fragilities and identified GVCs as an important transmission channel of international downturns. Our paper explores this issue at the micro level by designing a comprehensive taxonomy of GVC participation modes, and analyzing heterogeneities in the firms' behavior and performance during the Great Recession.

The empirical framework of this study is the Italian economy between 2008 and 2013, which represents an interesting laboratory to provide new insights in this field of research. In fact, the Italian system is a suitable environment for value-chain participation: an industry characterized by a large number of small suppliers, with high division of labor, and frequent inter-firm connections. Furthermore, the time-span under investigation permits us to shed light on differential behaviors of GVCs in times of crisis. While previous studies emphasized the role of value-chain connections in the cross-country synchronization of adverse shocks (*e.g.*, Baldwin, 2009), we show significant heterogeneities in how different forms of GVCs fared the trade collapse. We mainly focus on the firms' choice to engage in knowledge-creating strategies, but we also analyze real performances and provide some evidence on the nature of the shock experienced by GVC participants after 2008.

There are several features of the analysis that are worth emphasizing. First, we take advantage of a newly available dataset which is truly representative of the industrial system as a whole. The database comes from

[1]The concept of GVC comprises the full range of activities required to bring a product from its conception to its end use.

the widest survey administrated in a single European country –the MET survey on the Italian industry– and allows us to study even micro-sized companies with less than ten employees. These are typically excluded from previous works despite their prevalence (more than 90% in Italy) and the large benefits that they can gain from international linkages. We exploit the information in our dataset to outline a novel taxonomy of GVC participation modes that improves upon the use of aggregate data without relying on simplistic proxies. Our classification identifies four main *forms of GVC governance* –based on a firm's capability and degree of subordination– and allows for disentangling the effect of value-chain involvement from export-driven factors.

Second, we jointly analyze behaviors and performances to provide a more accurate picture of the firms' activity in the aftermath of the Great Recession. In terms of the GVC literature, this can be thought of as a more comprehensive approach to explore the phenomenon of *upgrading* (*i.e.*, the improvement of a firm's position along the value chain). Since the latter is unobservable, or at best difficult to measure, previous works typically made inference on the ex post variations in real outcomes.[2] Our analysis builds on this approach by taking an additional perspective into account; namely, while we still provide evidence on productivity and sales growth, we also focus on ex ante strategies aimed at increasing firm probability of upgrading. In particular, we study effects on extensive and intensive margins of innovation, R&D, and export activity, which we represent as *channels* of upgrading. We then interpret the combination of ex ante strategies and ex post performances as a more precise signal of a firm's advancement along the chain. Moreover, we further contribute to the debate on the Great Recession by providing suggestive insights on the shock experienced by GVCs in times of crisis. Finally, we take advantage of the panel dimension of our dataset to control for the possible self selection of more dynamic companies into GVCs. The main empirical strategy employs random-effects models with Mundlak correction (inclusion of regressors' time averages), but we also implement fixed-effects estimators, two-step system-GMM, and matching techniques to further take care of critical econometric issues.

Our findings highlight relevant heterogeneities in how GVC participants fared the crisis. Although firms involved in GVCs display a higher average propensity to upgrade, the mere affiliation to a value chain is not sufficient for success after the 2009-trade collapse. The specific form of governance, comprising the whole

[2] Morrison et al. (2008) point out some logical contradiction in previous approaches to the concept of upgrading.

system of relationships within a GVC, significantly affects firms' innovativeness and performance. *Relational GVCs*, involving skilled companies with low degrees of subordination, have a 4-to-6% higher probability of innovating and undertaking R&D projects. On the other hand, different forms of GVC participation – namely, *arm-length*, *quasi-hierarchical*, and *hierarchical*– have no significant premium in terms of innovative strategies. Interestingly, the involvement in GVCs also boosts the export probability of previously-non-internationalized companies.

The analysis of real performances provides consistent results. The greater upgrading propensity of relational GVCs is also reflected into their higher productivity (+6% in log scale) and sales growth (+9%), while other forms of governance are found, again, to have no advantage compared to domestic companies. In order to shed light on the shock experienced by GVCs in times of crisis we also perform a difference-in-differences (diff-in-diff) exercise around 2008. In particular, we analyze structural breaks in productivity and sales growth by exploiting the availability of a long panel for real outcomes and assuming pre-crisis stability of GVC participation. Even though this assumption is not negligible, we argue that the bias introduced in the model is likely to underestimate the actual magnitude of the shock (more on this issue in section 5.5). While our results document a strong contraction of sales growth for GVCs (-9%), we do not detect any sign of productivity drop in the aftermath of the Great Recession. This combined evidence points at a severe demand shock induced by the crisis and is compatible with previous arguments on how GVC input-output linkages amplified fluctuations in the demand for final goods. Importantly, we show that the shock mostly affected low-skill and subordinated suppliers, while relational GVCs were somewhat sheltered from the negative impact of the crisis. Finally, our results are stable across a number of robustness tests controlling for possible endogeneity, simultaneity bias, self selection, and for firms' unobserved heterogeneity.

The remainder of the paper is organized as follows. Section 2 presents the related literature and a further discussion of the main contributions. Section 3 outlines the empirical strategy and our taxonomy of GVC participation modes. Section 4 provides details on the dataset employed and descriptive statistics. Section 5 shows the results and section 6 concludes.

2. Related literature

Structure and performance of value chains are investigated from multiple viewpoints. A first strand of research provides theoretical foundation for the development of GVCs by focusing on vertical specialization and fragmentation of the production processes: *e.g.*, Findlay (1978), Dixit and Grossman (1982), and more recently Grossman and Rossi-Hansberg (2006), Markusen and Venables (2007), Antràs and Chor, 2013, Costinot et al. (2013), and Baldwin and Robert-Nicoud (2014).

A different perspective is offered by the *GVC approach* (*e.g.*, Gereffi and Korzeniewicz, 1994, Gereffi, 1999, and Humphrey and Schmitz, 2002) and the vast body of papers exploring the nature of inter-firm organizations within the value chains (*e.g.*, Sturgeon et al., 2008, Navas-Alemán, 2011). Their common view is that complex international relationships generate flows of managerial expertise and technical knowledge which in turn may stimulate the improvement of a firm's position along the GVC (*i.e.*, upgrading). The concept of governance[3] is considered to play a central role in affecting the growth prospects of the companies involved. While all value chain relationships imply some degree of information transmission, the extent to which knowledge is created, transferred, and adopted may vary considerably across modes of participation in the global production process (Kaplinsky, 2004; Pietrobelli and Rabellotti, 2011). In this regard, Gereffi et al. (2005) points at three key determinants of the GVC governance patterns: (i) the complexity of the transaction; (ii) the possibility to codify information; and (iii) the capability of the suppliers along the chain. Their interactions characterize different forms of governance and explain relevant heterogeneities in the learning opportunities of GVC participants. In particular, relational GVCs, comprising complex transactions and high-skill suppliers, are considered to offer the ideal conditions for the development of upgrading processes (Humphrey and Schmitz, 2002; see section 3.2 for a detailed discussion).[4] Altogether, the GVC approach provides a complementary perspective to the view of knowledge transfer given by the international production literature: the growth opportunities of a firm are not only affected by its choice on whether or not to be internationalized, but also, and especially, by its specific way of participating in the

[3]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, 1994).

[4]A collateral strand of the GVC literature specifically explores the link among forms of governance, upgrading, and learning mechanisms (see for instance, Schmitz, 2004, Bazan and Navas-Alemán, 2004, and Giuliani et al., 2005).

global production process.

Despite the large number of works examining GVCs on a theoretical basis, the empirical evidence at the micro level is still underwhelming. The vast majority of papers focus on case studies or limit the analysis to specific industries (Gereffi, 1999, Schmitz, 1999, Sturgeon, 2002, among many others), while only a few examples exploit plant-level data. Within this strand of the literature, Pietrobelli and Saliola (2008) focus on Thailand to document how the buyer involvement with local suppliers affects productivity, technology diffusion, and output growth. Similarly, Saliola and Zanfei (2009) find that knowledge-intense relationships are positively associated with the presence of global buyers in the market. Finally, Baldwin and Yan (2014) examine whether the integration of Canadian companies into GVCs fosters productivity growth.

The literature on the Italian system is rich, but mainly related to outsourcing, off-shoring, or export. Among these studies, Chiarvesio et al. (2010) focus on internationalization and innovation strategies of SMEs operating in industrial districts, while Accetturo et al. (2011) investigate the relationship between functional upgrading and performance. Working on the 2011-wave of the MET survey, Giovannetti et al. (2015) document a positive association between export and a firm's involvement in *filiére*. Finally, Giunta et al. (2012) analyze the impact of subcontracting on sales growth, while Agostino et al. (2014) document a productivity premium for skilled suppliers.

A parallel stream of research rethinks global networks in the light of the Great Trade Collapse of 2009. Baldwin (2009) relates value-chain linkages with the synchronization of adverse shocks across countries. His paper suggests that input-output connections played a critical role in the transmission of the crisis because the reduction in the final demand for goods decreased orders backwards along the GVCs. This issue is further analyzed by Bems et al. (2011) and Alessandria et al. (2011) who point at vertical specialization and inventory adjustments as potential channels of transmission of international downturns. Finally, Békés et al. (2011) and Accetturo and Giunta (2015) explore heterogeneities across the firms' position in a value chain.[5]

This paper contributes to the existing literature in several ways. First, we take advantage of a newly-available dataset containing relevant information on the involvement in GVC of a large sample of Italian

[5]Also on the recent crisis, Escaith et al. (2010) show the higher elasticity to international trade of companies in GVCs, while Boehm et al. (2014) focus on the role of multinational firms in the cross-country transmission of adverse shocks.

SMEs. Our data allow us to improve upon analyses on clusters or sectors, as well as to propose a more rigorous approach for the identification of value chains at the micro level. Previous works either assumed that GVCs are an economy-wide phenomenon, or exploited the firms' exporting status as a simple proxy. Instead, we rely on a rich availability of information to design a comprehensive taxonomy of GVCs and of their participation modes. Moreover, the focus on industrialized countries permits us to analyze the role of knowledge-intense relationships which was largely unexplored by previous works on least developed economies (Humphrey and Schmitz, 2002; Giuliani et al., 2005).

Second, we deal with the unobservability of the upgrading process by adding an additional perspective. Existent literature typically deduces upgrading from measures of performance, as they are positively affected by the improvement of a firm's position along the chain. While we still provide evidence on ex post productivity and sales growth, we also focus on the adoption of ex ante strategies aimed at increasing the likelihood of upgrading: extensive and intensive margins of innovation, R&D, and export. As far as we know, this is the only work exploring the effect of GVCs on the firms' propensity to engage in knowledge-creating activities.

Moreover, we contribute to the debate on the Great Recession by focusing on the 2008–2013 period and presenting some insights on the nature of the shock experienced by GVCs in the aftermath of the trade collapse. Importantly, we add a new element to this literature by showing relevant heterogeneities in how GVC participants fared the recent crisis. Finally, this is the first paper exploiting panel techniques to deal with critical econometric issues in the GVC approach.

3. Empirical methodology

This section presents the empirical strategy of the paper. First, we describe our approach in identifying GVCs and their different forms of governance. Then, we illustrate the econometric methodology employed to control for endogeneity, self selection, and firms' unobserved heterogeneity.

3.1. Identification of GVCs

The few empirical papers dealing with micro data typically employed export activity as a simple indicator of participation in a value chain. The aim of this work is to propose a more exhaustive measure that acknowledges the complexity of this phenomenon and possibly improves upon the traditionally used proxies.

Our approach combines survey data on export, import, type of the main good produced, and participation in global networks, to identify the firms which are most likely to be involved in GVCs.

Because intermediate products are typically employed in a broader production process, we regard exporters of semi-finished goods to be (reasonably) part of a GVC.[6] Similarly, a company importing its inputs *and* exporting final goods is totally integrated in an international framework and is expected to participate in a production on global scale. A certain degree of ambiguity arises when companies are, to some extent, internationalized; either import input factors *or* export final products. For this group, a firm's inclusion in our GVC proxy is conditioned on its involvement in global networks, as captured by the existence of "long-lasting and significant relationships with foreign companies".[7,8] Although this definition is not based on an objective scale, it leaves to the firm the evaluation of whether the international linkage is non-occasional and represents an important activity for its own business. This piece of information allows to rule out from our GVC measure firms that occasionally search for new markets and cheaper inputs (roughly 75% of the ambiguous cases).[9] However, we also test alternative definitions of GVCs excluding partially-internationalized companies (and thus precluding global networks to play any role) or adopting conservative thresholds for firm export activity (20% or 40% of total sales).[10] Results are largely in line with the ones presented in section 5.

3.2. Modes of participation in GVCs

Theoretical literature suggests that the learning opportunities of a firm may vary significantly across its possible modes of participation in a GVC. To explore this heterogeneity we propose a classification of the

[6]Note that the use of survey measures –*i.e.*, firms' self-assessments– solves potential problems linked to the ex post classification into different types of goods (tires, for instance, can be either intermediate, final products, or both). Self-declarations on the main activity permit us to avoid judgment calls and to exclusively rely on a firm's own perception about the main destination of its product.

[7]The questionnaire specifically asks for the existence of "significant and long-lasting relationships with foreign companies" as well as their scopes (trade, commercialization, common R&D projects, etc.). To the purpose of this section we only exploit aggregate information, while we employ data on the scope of the relationships for the definition of the different GVC participation modes (section 3.2).

[8]It is worth stressing that this measure does not uniquely identify GVCs. Fully-internationalized firms and exporters of intermediate goods are considered to be part of a value chain even without any long-term connection with foreign companies. This is crucial for the identification of arm-length suppliers, largely emphasized by the literature on GVCs (*e.g.*, Humphrey and Schmitz, 2002; Gereffi et al., 2005). See section 3.2 for a detailed discussion.

[9]This classification is only feasible for manufacturing firms. Companies in the service sectors are defined to be part of a GVC if they are internationalized and declare to have long lasting and significant relationships with foreign firms. Results are robust to the exclusion of service sectors from the sample.

[10]Throughout the paper we only rely on a dummy variable and do not impose any lower bound to identify exporters.

different forms of governance based upon the capability of suppliers and the strength of power relationships in a chain.

The first dimension has crucial implications for the learning prospects of a company. In fact, firms in GVCs need some skills not only to handle the expertise they already have, but also to access external sources of knowledge (Cohen and Levinthal, 1989). Moreover, multinational companies are more willing to transfer knowledge to skilled partners to reduce the risk of residual incompatibilities between the product design and the components manufactured (Puga and Trefler, 2010). Finally, higher capabilities also imply a certain degree of autonomy creating incentives for efficiency gains, accumulation of technical skills, and investments in creative activities.

In addition to the firms' own skill, the existence of power relationships can strongly affect the coordination mechanism within a GVC and the growth opportunities of its participants. Indeed, under the (legitimate or implicit) authority which is used to coordinate the division of labor, knowledge is typically treated as a scarce resource and concentrated in specialized functional units at the highest levels of the value chain. As a result, narrowly-specialized (subordinated) suppliers, with low technological know-how and no incentives for the transmission of innovative ideas upwards, are more likely to display low productivity gains and poor innovative attitudes.

Our taxonomy proxies firm capability and the degree of subordination with data on the affiliation to corporate groups, the existence of "long-lasting and significant relationships for trade purposes", and the degree of participation in the conception of the final product. The combination of this information allows us to identify four forms of GVC governance (in the spirit of Humphrey and Schmitz, 2002 and Gereffi et al., 2005) according to the following scheme:

1. *Arm-length*: suppliers participating in GVCs without any long-lasting and significant relationship for trade purposes.[11] This is the most market-like form of GVCs, implying negligible dependence between buyers and suppliers and involving transactions that are highly codifiable (standard or easily customized goods).

[11] This information is inferred from details on the scope of "significant and long-lasting relationships with foreign companies" (in the survey). Firms are considered to be involved in arm-length GVCs if the international relationship is not for trade purposes or if they declare to have no foreign connection at all.

2. *Hierarchical*: subsidiaries of corporate groups. The degree of subordination is at the maximum level since they are typically managerially controlled by a parent company (which is often the leader of the chain).[12,13]

3. *Quasi-hierarchical*: companies having long-lasting and significant relationships for trade purposes and no involvement in the conception of the final product.[14] Even without any formal control by a lead firm, quasi-hierarchical suppliers are strongly dependent on buyers providing detailed specifications for goods and production processes. In this regard, the existence of relevant commercial networks proxies for their strong dependence and subordination, while the absence of participation in the definition of the final product captures their low capability and marginal involvement in the decision process at the GVC level.

4. *Relational*: firms with long-lasting and significant trade-relationships and relevant involvement in the conception of the final product.[15] These companies engage in close inter-firm connections, but their capability ensures greater autonomy compared to quasi-hierarchical relationships. Differently from the previous form of governance, the active participation in the conception of the final product captures high capability of the supplier and its relevant involvement in the decision process within the GVC.

We regard these modes of participation to display heterogeneous behaviors and performances in times of crisis. First of all, we expect no significant role for hierarchical and quasi-hierarchical GVCs in which the existence of power relationships (together with the involvement of low-skill firms in the second mode) inhibits a companies' incentives to upgrade. On the other hand, relational GVCs combining low subordination and high suppliers' capability should provide the ideal environment for the development of upgrading strategies aimed at counteracting any negative shock induced by the Great Recession. Finally, we have mixed priors on arm-

[12]To derive this piece of data we match information on the affiliation to corporate groups with a dummy variable for parent companies (imposed equal to zero).

[13]In this regard, the international business literature emphasizes relevant differences in the possible forms of subsidiary mandates (see for instance the distinction between *competence-creating* vs. *competence-exploiting* subsidiaries –Cantwell and Mudambi, 2005– or *asset-exploiting* vs. *asset-seeking* activities –Le Bas and Sierra, 2002; Narula and Zanfei, 2005).

[14]Firms' involvement in the conception of the final product comes from the following question in the MET survey: "to what extent does your firm participate in the conception and definition of the final product for the market?". The survey allows answers on a scale from zero to four. Throughout the core of the paper, quasi-hierarchical suppliers are required to have no participation (0), but we also test alternative thresholds (1 or 2) with no significant changes in the results.

[15]Throughout the paper we simply require a positive threshold for a firm's involvement in the conception of the final product. However, we also test the robustness of our results to the adoption of alternative thresholds (greater than 1 or 2), or to different proxies of a firm's capability (share of graduated employees). For a detailed list of robustness checks see section 5.6.

length GVCs in which the absence of close connections implies a high degree of autonomy (that stimulates upgrading), but also limits the exchange of knowledge flows with partner firms. Moreover, occasional trade relationships are the most likely to be cut down when a negative shock occurs, thus exposing arm-length suppliers to higher demand fluctuations in times of crisis.

3.3. Econometric approach

The econometric analysis employs the taxonomy outlined in the previous sections to study the behavior of GVC participants during the Great Recession. In order to provide a detailed picture of the firms' activities and growth prospects, we focus on a broad array of knowledge-creating strategies as well as real outcomes between 2008 and 2013. In terms of the value-chain literature, this joint focus on strategies and performance can be thought of as a comprehensive approach to overcome the unobservability of upgrading. First, we analyze firm propensity to engage in activities that are likely to increase the probability of upgrading (*i.e.*, channels of upgrading). Then, we explore heterogeneities in ex post performances –productivity and sales growth– which are positively affected by the improvement of a firm's position along the chain.

The baseline equation tests the effect of GVC participation on the extensive margins of innovation, R&D, and export according to the following specification:[16]

$$Pr(Y_{it} = 1) = \Phi\left(\alpha^{\top} VC_{it-1} + \beta^{\top} X_{it-1} + \lambda_t + \Gamma_i + c_i + u_{it}\right), \tag{1}$$

where Y_{it} is the dummy dependent variable –*Innovation*, *R&D*, or *Export*– and VC_{it-1} is a vector of covariates measuring either the beginning-of-period value-chain participation (GVC_{it-1}), or the specific form of GVC governance ($Arm\text{-}length_{it-1}$, $Quasi\text{-}hierarchy_{it-1}$, $Hierarchy_{it-1}$, and $Relational_{it-1}$). Equation (1) is a standard reduced form including a rich set of covariates (X_{it-1}) to capture structural characteristics (size, age, sales, cash flow, market share, vertical integration, productivity) and behaviors (affiliation to networks or groups of firms, human capital, and R&D), as well as firm degree of internationalization aimed at purging export-driven factors.[17] We also include time effects (λ_t) and controls for the firms' belonging

[16] Notice that, although innovation and R&D are closely-related activities, they do not display a perfect correspondence when *innovation without R&D* is a widespread strategy. This is especially the case in economies dominated by SMEs such as the Italian system (Gottardi, 1996).

[17] To mitigate endogeneity issues all covariates are lagged once. However, we also propose specifications with further lags (L2

industry (12), region (20), or geographical province (110) (Γ_i) to capture common shocks that are time varying and permanent industrial/geographical effects. Finally, c_i is a factor controlling for firms' unobserved heterogeneity.

There are two main issues we need to take into account for assessing the effect of GVC participation on the firms' propensity to upgrade. The first one has to do with reverse causality, whereby GVCs do not foster upgrading processes but instead result from successful innovations and better performances. The second interrelated point is the possible self selection of more dynamic companies into GVCs. Because the adoption of external instruments is hardly feasible in our framework, we try address these issues in several alternative ways.

First of all, we alleviate problems of reverse causality by ruling out simultaneity bias. Matching current upgrading with lagged GVC involvement partially solves reverse causation but may leave residual endogeneity in case of relevant unobserved heterogeneity or high persistence of Y and VC. Dealing with unobserved heterogeneity in a binary-response framework is not trivial. On the one hand, standard random-effects (RE) models impose unrealistic assumptions on the type of heterogeneity that takes place (*i.e.*, c_i must be uncorrelated with the entire set of regressors).[18] On the other, fixed-effects models (that do not impose any hypothesis on c_i) are computationally difficult and introduce an incidental parameter problem leading to inconsistent estimates. Our strategy is in-between the two approaches and relies on RE-probit models augmented with the time average of each regressor (*i.e.*, *Mundlak-type controls*). In this way, we relax the assumption of independence between c_i and the set of covariates, and estimate the effect of each variable in terms of deviations from its time average.[19] Moreover, to further control for persistence of Y_{it}, we always provide results also for the subset of firms with $Y_{it-1} = 0$. This is particularly important when analyzing

for survey measures and L3 for balance-sheet variables) with unchanged results. A detailed definition of the variables employed is provided in Appendix.

[18] Let ε_{it} be the error term and Z be the full set of covariates (composed of VC_{it-1} and X_{it-1}). Pure RE models impose the strong hypothesis of independence between c_i and the Z_{it} (*i.e.*, $E[c_i|Z] = 0$, $cov[c_i, c_j|Z] = 0$ if $i \neq j$, $cov[\varepsilon_{it}, c_j|Z] = 0$ $\forall\, i, t, j$).

[19] Our estimator follows Wooldridge (2010) and can be viewed as a Mundlak version of the Chamberlain's assumption on the correlation between c_i and Z $\left(i.e., c_i|Z \sim N(\psi + \bar{z}_i, \sigma_a^2)\right)$. Notice that this approach is equivalent to a fixed effects model in which the heterogeneity is projected on the time-mean of the regressors ($\bar{Z}_i$), allowing to write the latent variable as $Y_{it}^* = \psi + \beta^\top Z_{it-1} + \theta^\top \bar{Z}_i + e_{it}$, with $e_{it} \sim N(0, 1)$. As usual, the estimator hinges crucially on the strict exogeneity of Z_{it-1} conditional on c_i. We verify this hypothesis by adding the vector Z_{it} to our specification and testing the significance of its estimates (as proposed by Wooldridge, 2010). The test never rejects the null (for any of the additional regressors), thus providing at least some justification for the strict exogeneity assumption.

firms' international propensity.[20]

In the unlikely case that residual heterogeneity is still affecting our findings, we also implement some alternative estimators allowing for the introduction of firm fixed effects. In section 5.3 we show the robustness of our results to the adoption of conditional logistic and linear probability (within estimators) models purging all the firms' (observable and unobservable) characteristics that are stable over time. Finally, we further take care of self selection by employing matching techniques (Coarsened Exact Matching) to recover a subsample of companies with the same ex ante probability of GVC participation. We then re-estimate our baseline specification for the new subsample of *balanced firms* to make inference on the treatment effect and provide additional robustness to our results.

The last econometric issue that is worth discussing is the possibility of correlated shocks. In other words, if there is a polarization of GVCs within specific industries or geographical areas, the set of parameters $\alpha^{\top}$ may be affected by the firms' reaction to unobserved shocks and no longer reflect the impact of GVC participation.[21] To tackle this concern we enrich our baseline specifications with an extensive set of time fixed effects specific for firm belonging industry (12 macro-industries $\times$ 3 periods), region (20 $\times$ 3), and geographical province (110 $\times$ 3).[22] This broad set of fixed effects permits us to control for most of the unobserved shocks induced by the Great Recession.

Further analyses are largely in line with the baseline specification. We take advantage of RE-tobit models (with Mundlak correction) for the intensive margins of innovation, R&D, or export and within estimators (with firm and time fixed effects) for performance variables. We also exploit a long panel of real outcomes to provide some insights on the shock experienced by GVCs during the Great Recession. In particular, we project our GVC proxies backwards (assuming stability over missing years) to employ diff-in-diff techniques and analyze structural breaks in productivity and sales growth around 2008 (more on this in section 5.5).

[20] Indeed, a positive association between GVCs and export status is intrinsic in the definitions of section 3.1 and 3.2. To rule out this spurious correlation, results on export premia are only reported for the subset of non-internationalized firms in $t-1$.

[21] This is the case if the crisis produced differential effects across industries and regions.

[22] It is worth noticing that this approach, together with the inclusion of firm-specific fixed effects, allows to purge the model from the possible omitted-variable bias induced by the absence of information on multi-product firms. On the one hand, any association between these companies and the set of dependent variables –as well as any stable mismeasurement of the GVC proxies– is captured by the firm fixed effects. On the other, if multi-product firms are more concentrated in certain industries or (northern) geographical regions, the set of interacted time effects should control for a large fraction of the residual time-varying component.

4. Data

The main source of data is the MET database on Italian firms, the widest survey administrated in a single European country. The original sample of the four waves –2008, 2009, 2011, and 2013– is composed of 25,000 cross-sectional observations and follows a disproportionate Bayesian scheme representative at the size, geographical region, and industry levels (see Table 1 for some details).[23] Differently from other datasets, the sample provides information on every size class –even micro-sized companies with less than ten employees– and refers to both manufacturing (60%) and service industries (40%). Its rich array of data is exploited for our taxonomy of GVC participation modes and for controls in the main specification.[24]

The survey also contains relevant information on export, R&D projects, and product/process innovations.[25] In addition to dichotomous answers, the questionnaire asks for firm expenditure in R&D (as a share of total sales) and for the share of income coming from exported goods, from products that are "new to the market" (radical product innovations) or "only new to the firm" (imitative products). While our analysis largely relies on the first type of information –we do not impose any threshold for *R&D* and *Export*–, we also exploit quantitative data for the intensive margins and some robustness checks.

Survey data are then matched with balance sheet information from Cribis D&B. The final estimation sample ranges from 30,000 to 10,000 observations, depending on the specification. Our econometric strategy hinges on the application of several selection-filters inducing a relevant contraction in the sample size. The major loss comes from the focus on the panel fraction of companies with complete balance-sheet information.[26] In addition, some observations are dropped because of unreasonable values (negative or nil assets, negative or nil sales) or to reduce the influence of outliers (balance sheet variables are censored at the 1%).

[23] The large number of interviews follows a scheme representative at the size-region-industry *stratum* which allows for an oversampling of medium-sized and large firms (a relatively rare phenomenon accounting for roughly 0.50% of the population). We purge potential distortions with the introduction of controls for a firm's size (log-number of employees or log of total assets) as well as firm-specific (conditional or unconditional) fixed effects. Moreover, we do not detect any sizable difference in our results if we employ (in a pooled framework) sampling weights designed to reproduce the population aggregates.

[24] We exploit information on import, type of the main good produced, corporate groups, global networks, and involvement in the conception of the final product for our proxies of GVC participation, while data on size, age, and human capital are employed as control variables in equation 1.

[25] The definitions in the questionnaire are in line with the Community Innovation Survey (CIS) and follow the guidelines provided by OECD and Eurostat (Frascati Manual for R&D and Oslo Manual for innovation).

[26] Balance sheet data are not available for family firms, a relevant fraction of the overall sample. This constraint, combined with the need of longitudinal data, induces a sample reduction of about 60%.

Table 1: Sample composition of the MET survey.

	2008	2009	2011	2013
Micro (1-9)	38.4%	60.0%	61.6%	48.1%
Small (10-49)	38.4%	26.0%	24.7%	33.6%
Medium (50-249)	19.5%	10.4%	10.6%	13.5%
Large (>250)	3.60%	3.50%	3.10%	4.80%
North	46.6%	39.8%	42.1%	40.2%
Center	32.0%	33.7%	31.8%	30.5%
South	21.4%	26.5%	26.1%	29.3%
High-tech	33.5%	29.1%	31.1%	31.9%
Non high-tech	66.5%	70.9%	68.9%	68.1%
# of firms	24896	22340	25090	25000

Notes: composition of the sample by firm size class (number of employees), geographical macro-region, and industrial macro-sector (high-tech sectors are: chemicals, plastic, means of transportation, engineering, electric and electronic equipment). The original sample is mainly stratified along 12 industries (see Table 3), 20 regions, and four size classes. The large amount of interviews is compatible with an oversampling of larger, more innovative, firms in the manufacturing sector, and of companies in certain geographical regions. The sampling scheme is performed with Bayesian models exploiting the observed frequencies of the previous waves. The survey is administrated via phone calls or via web with the assistance of a phone operator. The actual administration follows a preselection of the most suitable answerer. In the case of incoherent answers along the survey, firms are interviewed a second time as an additional control of validity. For further details about the sampling scheme, the administration methods, and the control procedures see Brancati (2012).

4.1. Descriptive statistics

Table 2 presents summary statistics for the main variables employed. Overall, 16% of the firms in the sample belong to our classification of GVCs (employing roughly 35% of total labor force in Italy): 28% are in relational value chains, while arm-length, quasi-hierarchical, and hierarchical relationships are 30%, 29%, and 14%, respectively. They also display quite a heterogeneous distribution across industries, with a prominent concentration in the chemical, electronic, engineering, transportation, and textile sectors (Table 3). Table 4 reports conditional statistics for innovation and R&D. Firms belonging to GVCs display a higher propensity to engage in knowledge-creating activities, with shares of dynamic companies that are two-to-four times larger than non-GVC firms. This phenomenon is strongly heterogeneous across forms of governance and is mainly driven by the higher dynamism of relational suppliers. The aim of the next section is to assess whether behind this positive association there is a causal nexus linking GVC participation and firm upgrading propensity in times of crisis.

5. Results

This section presents the results of the paper. First, we analyze the effect of GVC participation on the firms' probability to engage in innovation, R&D, and export activities which are aimed at promoting upgrading processes. Then, we explore heterogeneities by GVC forms of governance and discuss the results

Table 2: Descriptive statistics.

Variable	Type	Mean	Std.	Min	Max
GVC	Dummy	0.161	0.311	0.000	1.000
Arm-length	Dummy	0.047	0.201	0.000	1.000
Quasi-hierarchy	Dummy	0.046	0.231	0.000	1.000
Hierarchy	Dummy	0.023	0.144	0.000	1.000
Relational	Dummy	0.045	0.229	0.000	1.000
Innovation	Dummy	0.302	0.459	0.000	1.000
R&D	Dummy	0.150	0.357	0.000	1.000
Export	Dummy	0.240	0.427	0.000	1.000
%Prod_P	Bounded	0.045	0.172	0.000	1.000
%Prod_S	Bounded	0.032	0.135	0.000	1.000
%R&D	Bounded	0.009	0.051	0.000	2.500
%Exp	Bounded	0.101	0.213	0.000	1.000
Log-productivity	Continuous	10.51	1.105	-0.654	17.32
Log-sales	Continuous	14.74	1.636	10.35	18.87
Size	Continuous	2.441	1.399	0.693	10.72
Age	Continuous	2.704	0.933	0.000	7.607
Sales	Continuous	1.145	0.787	0.000	4.365
Cash flow	Continuous	0.024	0.106	-0.389	0.410
Market share	Bounded	0.029	0.070	0.000	0.496
Vertical integration	Continuous	0.268	0.280	0.000	0.951
Network	Dummy	0.367	0.482	0.000	1.000
Group	Dummy	0.134	0.340	0.000	1.000
Human capital	Bounded	0.076	0.173	0.000	1.000

Notes: descriptive statistics for the main variables employed. All measures are defined in Appendix.

Table 3: GVC participation across industries.

Industry	GVC	Arm-length	Hierarchy	Quasi-hierarchy	Relational
Food	15.2%	4.02%	1.25%	3.61%	6.13%
Textile	26.2%	8.98%	2.71%	6.64%	7.91%
Furniture	16.2%	5.54%	0.73%	4.14%	5.73%
Printing	14.8%	4.24%	1.44%	4.79%	4.27%
Chemical	38.3%	11.6%	7.16%	9.90%	9.67%
Machinery	22.0%	6.05%	2.42%	6.91%	6.61%
Transportation	29.5%	8.58%	5.57%	6.96%	8.41%
Engineering	31.3%	9.43%	5.09%	7.58%	9.17%
Electric	37.2%	11.1%	6.14%	8.58%	11.4%
Mineral	15.5%	4.98%	1.55%	4.32%	4.57%
Transports	15.6%	4.21%	1.06%	7.12%	3.22%
Services	10.6%	2.83%	1.46%	3.01%	3.28%

Notes: participation in GVC and forms of governance by industrial sector.

for the intensive margins. Finally, we test the effects on ex post performance –productivity and sales growth– and explore structural breaks in the aftermath of the 2009-trade collapse.

Table 4: Conditional innovativeness.

	Innovation	R&D
GVC = 0	18.7%	9.76%
GVC = 1	40.3%	34.0%
Arm-length = 1	38.1%	16.9%
Quasi-hierarchy = 1	32.3%	23.4%
Hierarchy = 1	31.9%	27.6%
Relational = 1	43.0%	40.2%

Notes: percentage of innovative firms (column 1) and companies with R&D projects (column 2) by GVC participation modes.

5.1. GVC participation and channels of upgrading

Column 1 of Table 5 presents the results for firms' innovativeness. On the top of structural characteristics and behaviors, GVC participation is found to induce a 4.1%-increase in a company's probability of introducing (at least one) product or process innovations.[27] Because Mundlak-type regressors net out persistent heterogeneity (including the higher average innovativeness of GVCs, $\mu(\text{GVC})$), this estimate can be interpreted as the innovation-premium generated by a firm's decision to start operating in the GVC.[28] The effect is even higher (6.6%) if we focus on the subsample of non-innovative companies in $t-1$ to address the possible reverse causality driven by the persistence of the innovation process (column 3). The other controls present coefficients that are in line with a priori expectations, with a predominant role played by firm structural characteristics (especially size), R&D, and degree of internationalization.

Column 2 of Table 5 presents coherent results for the extensive margins of R&D. Firms involved in GVCs show greater dynamic propensities, translating into a probability of undertaking R&D projects that is 3.1%-higher than other companies; 6.9% in the subsample of firms with no R&D expenditure in $t-1$ (column 4). Once again, the effect of GVC participation dominates the positive impact of internationalization and survives to our rich set of controls.

Finally, column 5 presents some evidence on the firms' probability of exporting. Since our proxy is by construction correlated with the dependent variable, we only focus on the subset of previously non-internationalized companies (10% in GVCs). Our results show that domestic firms participating in GVCs

[27] We do not find significant heterogeneities if we distinguish between the type of innovation introduced.

[28] Notice that the significance of most of the regressor means (also those that are not showed in the table) implicitly validates our need of relaxing the orthogonality conditions of standard RE-probit models.

are characterized by a 18.6%-higher probability to start exporting in time t. This evidence may be related to the role of knowledge acquisition from partners along the chain in the reduction of informational barriers to international trade.[29]

Table 5: GVC participation and channels of upgrading.

Sample:	Entire		$Y_{t-1}=0$		
Y:	$Innovation_t$	$R\&D_t$	$Innovation_t$	$R\&D_t$	$Export_t$
	(1)	(2)	(3)	(4)	(5)
GVC_{t-1}	0.041***	0.031**	0.066***	0.069***	0.186***
	[0.015]	[0.013]	[0.021]	[0.017]	[0.014]
$Size_{t-1}$	0.025***	0.023***	0.044***	0.035***	0.016**
	[0.008]	[0.008]	[0.008]	[0.006]	[0.007]
Age_{t-1}	0.075	-0.108**	0.046	-0.042	-0.035
	[0.063]	[0.044]	[0.046]	[0.034]	[0.038]
$Sales_{t-1}$	-0.019***	-0.033***	-0.003	-0.014***	-0.004
	[0.005]	[0.005]	[0.005]	[0.004]	[0.004]
Cash $flow_{t-1}$	0.122**	0.089*	0.054	0.041	-0.037
	[0.042]	[0.041]	[0.046]	[0.042]	[0.046]
Market $share_{t-1}$	0.004	0.008	-0.017	0.007	-0.023
	[0.021]	[0.015]	[0.034]	[0.018]	[0.023]
Vertical $integration_{t-1}$	-0.018	0.019	0.019	0.034**	0.039**
	[0.018]	[0.015]	[0.016]	[0.014]	[0.018]
$Network_{t-1}$	0.059***	0.059***	0.093***	0.068***	-0.033***
	[0.010]	[0.010]	[0.008]	[0.008]	[0.005]
$Group_{t-1}$	0.046***	0.006	0.003	0.002	-0.002
	[0.013]	[0.010]	[0.011]	[0.009]	[0.008]
Human $capital_{t-1}$	0.018	0.231***	0.047***	0.148***	0.119***
	[0.019]	[0.023]	[0.017]	[0.014]	[0.014]
$Export_{t-1}$	0.078***	0.119***	0.041***	0.044***	–
	[0.011]	[0.009]	[0.009]	[0.007]	–
$R\&D_{t-1}$	0.272***	–	0.181***	–	–
	[0.010]	–	[0.010]	–	–
Controls					
Time	yes	yes	yes	yes	yes
Industry (12)	yes	yes	yes	yes	yes
Region (20)	yes	yes	yes	yes	yes
Province (110)	yes	yes	yes	yes	yes
Mundlak correction	yes	yes	yes	yes	yes
μ(GVC)	0.055***	0.089***	-0.015	0.005	0.499***
# obs.	29754	29754	13172	14953	11603
Pseudo-R^2	0.145	0.214	0.155	0.136	0.464

Notes: RE-probit models with Mundlak correction (marginal effects). The dependent variable is listed in the second row (*Innovation*, *R&D*, and *Export* in column 1-3, 2-4, and 5, respectively). The left panel reports the estimates for the entire sample, while the right panel refers to subset of firms with $Y_{t-1}=0$. $\mu(\rho)$ refers to the time average of ρ. Additional covariates in the estimations (not shown): time average of the other regressors. All measures are defined in Appendix. *, **, *** denote, respectively, significance at 10%, 5%, and 1% level. Robust standard errors in brackets.

[29] In fact, most Italian firms regard informational barriers on foreign countries as the main obstacle to internationalization (see the Bank of Italy Survey of Industrial and Service Firms, Bronzini and D'Ignazio, 2012). In this regard, the involvement in a GVC may allow firms to cut down the sunk-costs linked to the acquisition of information on foreign markets, adjustment of products to foreign tastes, or creation of a distributional system and new business relationships.

5.2. Heterogeneity by GVC forms of governance

Theoretical literature suggests that the coordination mechanism within a GVC and the learning opportunities of its participants vary considerably across forms of governance. We argue that this heterogeneity may even be exacerbated in times of crisis because the firms' specific skills and environment may also affect the capacity of reaction to unexpected downturns. In particular, we regard relational GVCs, combining low degrees of subordination and high capabilities, to provide the ideal conditions for the development of upgrading strategies aimed at counteracting negative shocks. We empirically test this statement by enriching our baseline specifications with the definitions of governance outlined in section 3.2.

Table 6 presents the results. Column 1 clearly shows an effect of GVC participation on innovation that is highly heterogeneous, translating into a substantial innovative premium for relational GVCs and no significant impact for the other forms of governance. Again, this effect dominates our rich set of controls and is larger for the subsample of previously-non-innovative companies (5.9% in column 3). Column 2 shows consistent results for the investment in R&D: relational GVCs have a 3.7%-higher probability of investing in research activities (5.5% in column 4) while other modes of participation do not display any significant premium compared to domestic companies.

A somewhat different picture emerges from the firms' probability of exporting (column 5), whereby the impact of GVCs is found to be more homogeneous across forms of governance. However, the magnitude of the coefficients suggests that close informal relationships (in quasi-hierarchical and relational GVCs) may have a central role in the acquisition of information from partners along the chain. This, in turn, reduces the sunk costs associated to the penetration into foreign markets and results into a higher probability of export.

5.3. Unrestricted unobserved heterogeneity

The estimator employed so far controls for firm unobserved heterogeneity by conditioning c_i on the full set of regressors' means. We further take care of unobservable factors with alternative econometric approaches accounting for the inclusion of firm fixed effects and allowing us to avoid any restriction on the type of heterogeneity that takes place.

Table 7 shows the results of linear probability (odd columns) and fixed-effects logit models (even columns). The coefficients are qualitatively in line with our previous findings suggesting they are not driven by residual

Table 6: GVC forms of governance and channels of upgrading.

Sample:	Entire		$Y_{t-1}=0$		
Y:	$Innovation_t$	$R\&D_t$	$Innovation_t$	$R\&D_t$	$Export_t$
	(1)	(2)	(3)	(4)	(5)
$Arm\text{-}length_{t-1}$	-0.017	0.012	0.005	0.004	0.133***
	[0.013]	[0.011]	[0.017]	[0.014]	[0.018]
$Quasi\text{-}hierarchy_{t-1}$	0.021	-0.001	0.022	0.015	0.153***
	[0.014]	[0.013]	[0.021]	[0.017]	[0.019]
$Hierarchy_{t-1}$	-0.011	-0.004	-0.012	-0.035	0.052*
	[0.021]	[0.013]	[0.031]	[0.025]	[0.030]
$Relational_{t-1}$	0.035***	0.037***	0.059***	0.055***	0.181***
	[0.011]	[0.011]	[0.014]	[0.012]	[0.016]
Controls					
Time	yes	yes	yes	yes	yes
Industry (12)	yes	yes	yes	yes	yes
Region (20)	yes	yes	yes	yes	yes
Province (110)	yes	yes	yes	yes	yes
Mundlak correction	yes	yes	yes	yes	yes
μ(Arm-length)	0.029*	0.003	0.042*	0.001	0.411***
μ(Quasi-hierarchy)	-0.022	0.011	-0.042	-0.004	0.354***
μ(Hierarchy)	-0.006	0.001	0.003	-0.011	-0.099***
μ(Relational)	0.011	0.119***	-0.013	0.064***	0.358***
# obs.	29754	29754	13172	14953	11603
Pseudo-R^2	0.146	0.197	0.159	0.161	0.475

Notes: RE-probit models with Mundlak correction (marginal effects). The dependent variable is listed in the second row (*Innovation*, *R&D*, and *Export* in column 1-3, 2-4, and 5, respectively). The left panel reports the estimates for the entire sample, while the right panel refers to subset of firms with $Y_{t-1}=0$. $\mu(\rho)$ refers to the time average of ρ. Additional covariates in the estimations (not shown) follow the specification in Table 5. *, **, *** denote, respectively, significance at 10%, 5%, and 1% level. Robust standard errors in brackets.

unobserved heterogeneity.[30] Furthermore, we obtain similar results when implementing two-step system-GMM estimators on a synthetic (continuous) measure of firm innovativeness (see the robustness checks in section 5.6).

5.4. Intensive margins

This section explores the effect of GVC participation on the intensive margins of innovation, R&D, and export. We proxy the firms' innovativeness with two alternative measures: the share of sales from products that are new to the market –capturing the weight of radical product innovations (*%Prod_P*)– and from goods that are only new to the company –including softer forms like imitative products (*%Prod_S*).[31] Similarly, we measure R&D intensity with the firms' expenditure in R&D (as a share of total sales, *%R&D*) and export intensity as the share of sales from exported products (*%Exp*).

Table 8 reports the results of RE-tobit models with Mundlak correction. The estimates suggest that GVC

[30] Table 7 also shows the lower propensity of quasi-hierarchical GVCs in investing in R&D projects.

[31] These measures reflect a firm's own perception on the innovativeness embedded in its new products. Differently from previous results we are now excluding process innovations whose intensive margins are difficult to proxy.

Table 7: GVC forms of governance and channels of upgrading: controlling for unobserved heterogeneity.

Y:	Innovation$_t$		R&D$_t$		Export$_t$	
	(1)	(2)	(3)	(4)	(5)	(6)
Arm-length$_{t-1}$	-0.011	0.254	0.005	0.462	0.081***	0.686
	[0.011]	[0.275]	[0.009]	[0.333]	[0.010]	[0.559]
Quasi-hierarchy$_{t-1}$	-0.001	0.311	-0.030***	-0.584	0.142***	2.681***
	[0.0104]	[0.318]	[0.009]	[0.369]	[0.012]	[0.695]
Hierarchy$_{t-1}$	0.0199	0.373	0.007	-0.458	0.032*	1.689**
	[0.0163]	[0.466]	[0.013]	[0.513]	[0.016]	[0.831]
Relational$_{t-1}$	0.027***	0.439*	0.029***	0.676**	0.143***	3.352***
	[0.009]	[0.241]	[0.007]	[0.279]	[0.009]	[0.678]
Fixed effects						
Time	yes	yes	yes	yes	yes	yes
Firm	yes	yes	yes	yes	yes	yes
# obs.	18801	2504	18801	1592	18801	7889
R^2	0.165	–	0.147	–	0.429	–

Notes: linear probability (column 1, 3, and 5) and conditional logistic models (column 2, 4, and 6) with time and firm fixed effects (coefficients). The dependent variable is listed in the top row (*Innovation*, *R&D*, and *Export* in column 1-3, 2-4, and 5-6, respectively). Additional covariates in the estimations (not shown) follow the specification in Table 5 (excluding Munldak-type regressors). *, **, *** denote, respectively, significance at 10%, 5%, and 1% level. Standard errors in brackets (robust in column 1, 3, and 5).

participation, especially in the relational form, has a relevant impact also on the magnitude of the innovation undertaken. Importantly, the effect is stronger for the introduction of truly innovative products (column 1 and 5) than for softer innovations such as imitative goods (column 2 and 6). Again, we find similar results for R&D (column 3 and 7) and a more homogeneous effect for the share of export (column 4 and 8).

5.5. Performance

Having established the effect of GVC participation on the firms' strategic behavior, we now turn the attention on their productivity and sales growth. This additional focus can be viewed as a complementary perspective to our analysis of ex ante activities and allows us to provide some insights on the shock experienced by GVCs in the aftermath of the Great Recession. While, due to data limitations, we are not able to study the behavior of GVCs in normal times, the availability of a long panel for real outcomes offers the chance to perform a diff-in-diff exercise around the crisis. We do so by exploiting balance-sheet data from 2004 to 2013 and projecting backwards the 2008-values of our GVC proxies, thus assuming stability over missing years. We then employ within estimators (with firm and time fixed effects) and interaction terms with pre-crisis (τ = 2004–2008) and crisis (τ = 2009–2013) dummies ($\mathbb{1}(\tau)$) to analyze structural breaks

Table 8: GVC forms of governance and channels of upgrading: intensive margins.

Sample:	Entire				$Y_{t-1}=0$			
Y:	%Prod_P$_t$	%Prod_S$_t$	%R&D$_t$	%Exp$_t$	%Prod_P$_t$	%Prod_S$_t$	%R&S$_t$	%Exp$_t$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Arm-length$_{t-1}$	3.367	3.346	1.875***	7.547***	3.519	-0.811	2.374***	11.75***
	[2.741]	[2.265]	[0.573]	[0.746]	[3.841]	[3.339]	[0.785]	[1.291]
Quasi-hierarchy$_{t-1}$	3.753	-1.060	-0.693	8.293***	11.36***	5.631	-0.741	11.99***
	[3.113]	[2.611]	[0.588]	[0.805]	[4.262]	[3.949]	[0.921]	[1.564]
Hierarchy$_{t-1}$	3.164	-7.527**	-1.177	3.390***	6.091	-12.47**	-0.864	0.743
	[4.183]	[3.238]	[0.794]	[1.246]	[6.289]	[5.461]	[1.267]	[2.500]
Relational$_{t-1}$	6.568***	3.549*	1.389***	9.051***	6.344**	7.171***	2.423***	13.71***
	[2.266]	[1.854]	[0.463]	[0.666]	[3.182]	[2.678]	[0.652]	[1.269]
Controls								
Time	yes	yes	yes	yes	yes	yes	yes	yes
Industry (12)	yes	yes	yes	yes	yes	yes	yes	yes
Region (20)	yes	yes	yes	yes	yes	yes	yes	yes
Province (110)	yes	yes	yes	yes	yes	yes	yes	yes
Mundlak correction	yes	yes	yes	yes	yes	yes	yes	yes
μ(Arm-length)	1.322	1.764	-0.0499	18.63***	3.711	18.03***	-1.481	30.44***
μ(Quasi-hierarchy)	3.555	3.109	3.711***	38.99***	-6.819	-4.124	2.192	43.99***
μ(Hierarchy)	-3.100	9.542**	3.024**	3.182*	3.127	4.152	0.101	10.91***
μ(Relational)	34.89***	21.92***	9.281***	42.81***	37.42***	19.11***	7.266***	45.44***
# obs.	26515	26515	26504	29756	13576	13576	14285	11484

Notes: RE-tobit models withMundlak correction. The dependent variable is listed in the second row (*%Prod_P*, *%Prod_S*, *%R&D*, and *%Exp* in column 1-5, 2-6, 3-7, and 4-8, respectively). The left panel reports the estimates for the entire sample, while the right panel refers to subset of firms with $Y_{t-1}=0$. $\mu(\rho)$ refers to the time average of ρ. Additional covariates in the estimations (not shown) follow the specifications of *Innovation* (for column 1, 2, 5, 6), *R&D* (for column 3, 7), and *Export* (for column 4, 8) of Table 5. All measures are defined in Appendix. *, **, *** denote, respectively, significance at 10%, 5%, and 1% level. Robust standard errors in brackets.

between the two periods.[32]

Before showing the results, it is worth discussing the measurement error and the bias induced by our assumption of GVC pre-crisis stability. While we correctly identify firms in times of crisis, the backward projection of their status implies a mismeasurement of companies exiting or entering into a GVC before 2008. We regard the first type of error to be relatively negligible because internationalized firms are unlikely to withdraw from foreign markets in times of low domestic demand.[33] Indeed, 2011-census data on Italian firms show a 5%-increase in the overall number of exporters, with a marginal share of companies exiting international markets within the same period.[34] Thus, if any measurement error occurs, it should mainly concern firms with a delayed entrance into GVCs.[35] If this is the case, the productivity-gap between inter-

[32]The new estimating equation is $Y_{it}=\gamma_0+\alpha_1^\top\left[VC_{it-1}\times\mathbb{1}(\text{pre-crisis})\right]+\alpha_2^\top\left[VC_{it-1}\times\mathbb{1}(\text{crisis})\right]+\beta^\top X_{it-1}+\lambda_t+c_i+u_{it}$, where Y_{it} is either productivity or sales growth, c_i is the firm-specific fixed effect, and $\mathbb{1}$(pre-crisis) and $\mathbb{1}$(crisis) are dummy variables identifying the pre-crisis (2004–2008) and crisis (2009–2013) periods.

[33]Compared to other countries, the Italian economy was already performing poorly between 2004 and 2008. The average annual GDP growth was 1.45 percentage points lower that the one of OECD countries (-60%); 1.31 if compared to the European Union (18 countries).

[34]See *L'Italia nell'Economia Internazionale*, ISTAT (2012).

[35]Notice that this type of error is unlikely to regard relational GVCs relying on the existence of long-lasting relationships which are, by definition, stable over time.

nationalized and non-internationalized companies (largely emphasized by Melitz, 2003, Bernard et al., 2003, and many others)[36] should ensure a downward bias for the *pre-crisis* estimates of GVC participation. In fact, our proxies for GVCs before 2008 are grouping together highly productive companies (actually) involved in GVCs, with relatively less productive firms who engaged in international linkages only at a later time. As a result, any *negative* structural break on productivity and sales growth across periods may be interpreted as a *lower bound* for the actual shock.

Table 9 presents the results. In the two sub-periods, GVCs displayed a significant productivity premium on aggregate, but mainly confined to relational forms of governance (column 1 and 2).[37] These findings support our previous results and confirm the crucial role played by firm capacity in affecting upgrading along a GVC. Interestingly, the comparison of pre- and post-crisis coefficients does not highlight any significant productivity shock across time.[38]

The dynamic of sales growth draws a rather different picture. While the effect of relational GVCs is again positive and significant in both periods, other forms of governance experienced strong contractions compared to their pre-crisis trends. On average, the sales growth of firms in GVCs dropped by 9.2 percentage points notching down their positive premium in normal times. This combined evidence is compatible with a strong demand shock for firms involved in GVCs and with previous arguments on the role of global networks in the transmission of the crisis (Baldwin, 2009). Importantly, the shock was highly non-homogeneous, being more severe for low-skill firms (quasi-hierarchical) and for companies engaging in occasional relationships (arm length). Conversely, relational suppliers appeared to be somewhat sheltered from the negative effects of the crisis.

5.6. Additional robustness

To test the validity of the results we run a number of additional robustness checks, mainly aimed at addressing reverse causality, self selection, and the possibility of unobserved shocks:[39]

[36] See also Clerides et al. (1998), Bernard and Jensen (1999), Delgado et al. (2002), Yeaple (2005), Van Biesebroeck (2005), Castellani and Zanfei (2007), Fabling and Sanderson (2013), among many others.

[37] Results are qualitatively similar (albeit not always significant) if we employ TFP (Levinsohn and Petrin, 2003) in place of value added per worker.

[38] The change in the magnitude of the coefficient (-1.14%) is not significantly different from zero (p-value = 0.651).

[39] Results of all the robustness checks are available upon request.

Table 9: GVC participation, forms of governance, productivity, and sales growth: diff-in-diff.

Y:	ΔLog-productivity$_t$				ΔLog-sales$_t$			
τ:	Pre-crisis	Crisis	Pre-crisis	Crisis	Pre-crisis	Crisis	Pre-crisis	Crisis
	(1)		(2)		(3)		(4)	
GVC$_{t-1}\times\mathbb{1}(\tau)$	0.0544***	0.0430***			0.0780***	-0.0141		
	[0.0173]	[0.0164]			[0.0152]	[0.0145]		
Arm-length$_{t-1}\times\mathbb{1}(\tau)$			-0.0231	-0.0159			-0.0269	-0.112***
			[0.0291]	[0.0268]			[0.0268]	[0.0291]
Quasi-hierarchy$_{t-1}\times\mathbb{1}(\tau)$			0.0113	-0.0121			0.0915***	0.0384
			[0.0316]	[0.0316]			[0.0301]	[0.0302]
Hierarchy$_{t-1}\times\mathbb{1}(\tau)$			0.0141	0.0111			0.00569	0.00443
			[0.0153]	[0.0144]			[0.0632]	[0.0630]
Relational$_{t-1}\times\mathbb{1}(\tau)$			0.0541***	0.0586***			0.105***	0.0890***
			[0.0108]	[0.0133]			[0.0107]	[0.0127]
Fixed effects								
Time	yes		yes		yes		yes	
Firm	yes		yes		yes		yes	
# obs.	19234		19234		19234		19234	
R^2	0.089		0.095		0.104		0.111	

Notes: within estimators with firm and time fixed effects. The dependent variable is listed in the first row (Δ*Log-productivity* and Δ*Log-sales* in column 1-2 and 3-4, respectively). The effect of GVC and GVC forms of governance is allowed to vary in times of crisis (overall coefficient reported). $\mathbb{1}(\tau)$ is a dummy variable identifying the sub-period τ (listed in the second row). Pre-crisis and crisis periods refer to 2004-2008 and 2009-2013, respectively. Additional covariates in the estimations (not shown) follow the specification in column 2 of Table 5 (excluding Munldak-type regressors). All measures are defined in Appendix. *, **, *** denote, respectively, significance at 10%, 5%, and 1% level. Robust standard errors in brackets.

- we employ a mixed strategy relying on matching techniques to further explore the issue of self selection. First we exploit Coarsened Exact Matching models (Iacus et al., 2011) to select a subsample of firms with the same ex ante probability of GVC participation (the treatment variable).[40] Then, we repeat the analyses of section 5 on the new balanced sample;

- we test alternative definitions of GVCs based on more conservative thresholds for firm export activity (20% or 40% of firm total sales), for the involvement in the conception of the final product, and different proxies for firm capability (median and 75^{th} percentile of the share of graduated employees);

- we adopt minimum thresholds for the extensive margins of R&D and export (5%-10% and 20% of sales, respectively);

- we include time effects that are specific for the firms' belonging industry (12×3), region (20×3), and

[40] Firms are matched by age, size, region, industry, human capital, and productivity. Our choice to employ CEM rather than standard propensity-score matching techniques is driven by its appealing properties in the estimation of causal effects (reduced covariate imbalance between treated and control groups). Results are however robust to the choice of alternative matching models.

province (110×3) to control for unobservable correlated shocks;

- we implement multivariate probit models (with Mundlak correction) to control for third party factors affecting firm innovativeness, R&D propensity, and export status. This approach accounts for the simultaneity of the phenomena allowing for a correlation across error terms;
- we exclude from the estimation sample the service sector and adopt alternative clustering of the standard errors (industry, region –with bootstrapping–, or province, as well as two-way clustering at the industry-region and firm-industry levels);
- we employ within estimators and two-step system-GMM models on a synthetic measure of firms' innovativeness (the first principal component of R&D and innovation);[41]
- we enrich the matrix X_{it-1} with further lags for the control variables ($t-2$, or $t-3$), dummies for the legal form of the company, for firms' productivity (log-value added per worker, or TFP as computed by Levinsohn and Petrin, 2003), and financial status (leverage and composition of funding).

In all cases results are largely unchanged.

6. Concluding remarks

This paper takes advantage of a newly-available survey to explore strategies and performance of GVCs in the aftermath of the Great Recession. The analysis exploits a rich set of information on Italian SMEs to design a comprehensive taxonomy of the possible GVC participation modes and overcome some limitations of the previously-used proxies. The empirical strategy employs our classification to investigate the firms' innovativeness, productivity, and sales growth between 2008 and 2013.

Our results highlight relevant heterogeneities in how GVC participants fared the recent crisis. Although the involvement in a GVC has a positive (average) effect on the firms' business activities, the mere affiliation to a value chain is not sufficient for a company's success during the Great Recession. The specific modes of

[41] Two-step system-GMM models also allow for instrumenting endogenous (and predetermined) variables with appropriately-lagged levels and first differences. The Arellano-Bond test of autocorrelation of the error term and the Hansen J-test do not detect any form of misspecification, suggesting that our are results are not driven by residual unobserved heterogeneity or endogeneity of the GVC participation modes.

participation in the global production process strongly affects both the firms' performance, and propensity to engage in knowledge-creating strategies. Relational GVCs, comprising skilled firms with low degree of subordination, have a 4-to-6% higher probability of innovating and investing in R&D projects. On the other hand, different forms of value chains display no significant premium compared to domestic companies. This heterogeneity is also reflected in the dynamic of productivity and sales growth.

Due to data limitations we are not directly able to assess the effect of GVC participation on the firms' strategies in normal times, however the analysis of ex post performances provides some evidence on structural breaks induced by the Great Recession. A diff-in-diff exercise highlights a strong reduction in sales growth after 2008 (-9% in log-scale) while not detecting any sign of productivity drop within the same period. This combined evidence points at a severe demand shock hitting GVCs in times of crisis, and confirms previous arguments on the role of global networks in the transmission of international downturns. Importantly, we show that the contraction was substantial for lowly-capable and subordinated suppliers, while relational GVCs were somewhat shielded from the effects of the crisis.

References

Accetturo, A., Giunta, A., 2015. Global value chains and the Great Recession: Evidence from Italian and German firms. Mimeo.

Accetturo, A., Giunta, A., Rossi, S., 2011. The Italian firms between crisis and the new globalization. Bank of Italy Occasional Papers 86.

Agostino, M., Giunta, A., Nugent, J., Scalera, D., Trivieri, F., 2014. The importance of being a capable supplier: Italian industrial firms in global value chains. International Small Business Journal (forthcoming).

Alessandria, G., Kaboski, J. P., Midrigan, V., 2011. US trade and inventory dynamics. American Economic Review 101 (3), 303–07.

Antràs, P., Chor, D., 2013. Organizing the global value chain. Econometrica 81 (6), 2127–2204.

Baldwin, J., Yan, B., 2014. Global value chains and the productivity of Canadian manufacturing firms. Economic Analysis (EA) Research Paper Series 90.

Baldwin, R., Robert-Nicoud, F., 2014. Trade-in-goods and trade-in-tasks: An integrating framework. Journal of International Economics 92 (1), 51–62.

Baldwin, R. E., 2009. The great trade collapse: Causes, consequences and prospects. CEPR.

Bazan, L., Navas-Alemán, L., 2004. The underground revolution in the Sinos Valley: A comparison of upgrading in global and national value chains. Local Enterprises in the Global Economy: Issues of Governance and Upgrading 3, 110–139.

Békés, G., Halpern, L., Koren, M., Muraközy, B., 2011. Still standing: How European firms weathered the crisis. The third EFIGE policy report. Bruegel Blueprint Series 15.

Bems, R., Johnson, R. C., Yi, K.-M., 2011. Vertical linkages and the collapse of global trade. American Economic Review 101 (3), 308–312.

Bernard, A., Eaton, J., Jenson, B., Kortum, S., 2003. Plants and productivity in international trade. American Economic Review 93 (4), 1268–1290.

Bernard, A., Jensen, B., 1999. Exceptional exporter performance: Cause, effect, or both? Journal of International Economics 47 (1), 1–25.

Boehm, C., Flaaen, A., Pandalai, N., 2014. Input linkages and the transmission of shocks: Firm-level evidence from the 2011 Tōhoku earthquake. Mimeo.

Brancati, R., 2012. Crisi Industriale e crisi fiscale. Rapporto MET 2012. Le relazioni delle imprese, le criticitá, il fisco e le politiche pubbliche. Meridiana Libri.

Bronzini, R., D'Ignazio, A., 2012. Bank internationalization and firm exports: Evidence from matched firm-bank data. EFIGE Working Paper 59.

Cantwell, J., Mudambi, R., 2005. MNE competence-creating subsidiary mandates. Strategic Management Journal 26 (12), 1109–1128.

Castellani, D., Zanfei, A., 2007. Internationalisation, innovation and productivity: How do firms differ in Italy? World Economy 30 (1), 156–176.

Chamberlain, G., 1980. Analysis of covariance with qualitative data. Review of Economic Studies 47 (1), 225–238.

Chiarvesio, M., Di Maria, E., Micelli, S., 2010. Global value chains and open networks: The case of Italian industrial districts. European Planning Studies 18 (3), 333–350.

Clerides, S., Lach, S., Tybout, J., 1998. Is learning by exporting important? Micro-dynamic evidence from Colombia, Mexico, and Morocco. Quarterly Journal of Economics 113, 903–947.

Cohen, W., Levinthal, D., 1989. Innovation and learning: The two faces of R&D. Economic Journal 99, 569–596.

Costinot, A., Vogel, J., Wang, S., 2013. An elementary theory of global supply chains. Review of Economic Studies 80 (1), 109–144.

Delgado, M., Farinas, J., Ruano, S., 2002. Firm productivity and export markets: A non-parametric approach. Journal of International Economics 57 (2), 397–422.

Dixit, A. K., Grossman, G. M., 1982. Trade and protection with multistage production. Review of Economic Studies 49 (4), 583–594.

Escaith, H., Lindenberg, N., Miroudot, S., 2010. International supply chains and trade elasticity in times of global crisis. World Trade Organization Working Paper ERSD-2010-08.

Fabling, R., Sanderson, L., 2013. Exporting and firm performance: Market entry, investment and expansion. Journal of International Economics 89 (2), 422–431.

Findlay, R., 1978. An "Austrian" model of international trade and interest rate equalization. Journal of Political Economy, 989–1007.

Gereffi, G., 1994. The organization of buyer-driven global commodity chains: How US retailers shape overseas production networks. Contributions in Economics and Economic History, 95–95.

Gereffi, G., 1999. International trade and industrial upgrading in the apparel commodity chain. Journal of International Economics 48 (1), 37–70.

Gereffi, G., Humphrey, J., Sturgeon, T., 2005. The governance of global value chains. Review of International Political Economy 12 (1), 78–104.

Gereffi, G., Korzeniewicz, M., 1994. Commodity chains and global capitalism. Westport: Praeger.

Giovannetti, G., Marvasi, E., Sanfilippo, M., 2015. Supply chains and the internalization of SMEs: Evidence from Italy. Small Business Economics 44, 845–865.

Giuliani, E., Pietrobelli, C., Rabellotti, R., 2005. Upgrading in global value chains: Lessons from Latin American clusters. World Development 33 (4), 549–573.

Giunta, A., Nifo, A., Scalera, D., 2012. Subcontracting in Italian industry: Labour division, firm growth and the North–South divide. Regional Studies 46 (8), 1067–1083.

Gottardi, G., 1996. Technology strategies, innovation without R&D: And the creation of knowledge within industrial districts. Journal of Industry Studies 3 (2), 119–134.

Grossman, G. M., Rossi-Hansberg, E., 2006. Trading tasks: A simple theory of offshoring. NBER Working Paper 12721.

Humphrey, J., Schmitz, H., 2002. How does insertion in global value chains affect upgrading in industrial clusters? Regional Studies 36 (9), 1017–1027.

Iacus, S., King, G., Porro, G., 2011. Causal inference without balance checking: Coarsened exact matching. Political Analysis 20, 1–24.

Kaplinsky, R., 2004. Spreading the gains from globalization: What can be learned from value-chain analysis? Problems of Economic Transition 47 (2), 74–115.

Le Bas, C., Sierra, C., 2002. Location versus home country advantages in R&D activities: Some further results on multinationals' locational strategies. Research policy 31 (4), 589–609.

Levinsohn, J., Petrin, A., 2003. Estimating production functions using inputs to control for unobservables. Review of Economic Studies 70 (2), 317–341.

Markusen, J. R., Venables, A. J., 2007. Interacting factor endowments and trade costs: A multi-country, multi-good approach to trade theory. Journal of International Economics 73 (2), 333–354.

Melitz, M., 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. Econometrica 71 (6), 1695–1725.

Morrison, A., Pietrobelli, C., Rabellotti, R., 2008. Global value chains and technological capabilities: A framework to study learning and innovation in developing countries. Oxford Development Studies 36 (1), 39–58.

Mundlak, Y., 1978. On the pooling of time series and cross section data. Econometrica 46 (1), 69–85.

Narula, R., Zanfei, A., 2005. Globalisation of innovation. Oxford: Oxford University Press.

Navas-Alemán, L., 2011. The impact of operating in multiple value chains for upgrading: The case of the Brazilian furniture and footwear industries. World Development 39 (8), 1386–1397.

Pietrobelli, C., Rabellotti, R., 2011. Global value chains meet innovation systems: Are there learning opportunities for developing countries? World Development 39 (7), 1261–1269.

Pietrobelli, C., Saliola, F., 2008. Power relationships along the value chain: Multinational firms, global buyers and performance of local suppliers. Cambridge Journal of Economics 32 (6), 947–962.

Puga, D., Trefler, D., 2010. Wake up and smell the ginseng: International trade and the rise of incremental innovation in low-wage countries. Journal of Development Economics 91 (1), 64–76.

Saliola, F., Zanfei, A., 2009. Multinational firms, global value chains and the organization of knowledge transfer. Research Policy 38 (2), 369–381.

Schmitz, H., 1999. Global competition and local cooperation: Success and failure in the Sinos Valley, Brazil. World Development 27 (9), 1627–1650.

Schmitz, H., 2004. Local enterprises in the global economy: Issues of governance and upgrading. Edward Elgar Publishing.

Sturgeon, T., 2002. Modular production networks: A new American model of industrial organization. Industrial and Corporate Change 11 (3), 451–496.

Sturgeon, T., Van Biesebroeck, J., Gereffi, G., 2008. Value chains, networks and clusters: Reframing the global automotive industry. Journal of Economic Geography 8, 297–321.

Van Biesebroeck, J., 2005. Exporting raises productivity in sub-Saharan African manufacturing firms. Journal of International Economics 67 (2), 373–391.

Wooldridge, J. M., 2010. Econometric analysis of cross section and panel data. MIT press.

Yeaple, S., 2005. A simple model of firm heterogeneity, international trade, and wages. Journal of International Economics 65 (1), 1–20.

Appendix: variable definition

Variable name	Definition
GVC	dummy for global value chains.[a]
Arm-length	dummy for arm-length GVCs.
Quasi-hierarchy	dummy for quasi-hierarchical GVCs.
Hierarchy	dummy for hierarchical GVCs.
Relational	dummy for relational GVCs.[b]
Innovation	dummy for the introduction of (at least one) product or process innovations.[c]
R&D	dummy for R&D activity (independently by the expenditure in research projects).[d]
Export	dummy for export activity (independently by the amount exported).
%Prod_P	share of sales from products that are new to the market (radical product innovations).
%Prod_S	share of sales from products that are only new to the firm (imitative products).
%R&D	R&D expenditure/total sales.
%Exp	sales from exported products/total sales.
Size	ln(1 + #employees).
Age	ln(1 + years of age).
Sales	total sales/total assets.
Cash flow	(ebit – interest payments – non-operating income – extraordinary items)/total assets.
Market share	share of firm's sales over the aggregated turnover of the belonging industry (2-digit).
Vertical integration	value added/total sales.
Network	dummy for long-lasting and significant relationships with other companies (for any purpose).
Group	dummy for corporate groups.
Human capital	share of graduated employees.
Log-productivity	ln(value added/#employees).
Log-sales	ln(sales).

[a] GVC is defined in section 3.1.

[b] Arm-length, Hierarchy, Quasi-hierarchy, and Relational are defined in section 3.2.

[c] The definitions of product and process innovations are in line with the guidelines provided by OECD and Eurostat (Oslo manual). A product innovation is defined as the "introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics". A process innovation is considered the "implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software".

[d] The definition of R&D is in line with the guidelines provided by OECD and Eurostat (Frascati manual). R&D projects comprise "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications".