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Abstract

This paper combines various literatures on Global Value Chains (GVC), Economic Complexity and Evolutionary Economic Geography. The objective is to assess the role of regional capabilities and GVC participation in fostering economic complexity in 236 NUTS2-regions in Europe. Our results suggest there is no such thing as a common path of economic upgrading across EU regions. Regions with high economic complexity tend to keep their advantageous positions, as they are capable of benefitting from both regional capabilities (as proxied by a high relatedness between local activities) and external linkages in terms of GVC participation. Conversely, low-complex regions do not benefit from GVC participation, unless their regional capabilities (in terms of relatedness density) are also stronger.

JEL codes: B52, F23, O19, O33, R10

Keywords: Economic Complexity, Evolutionary Economic Geography, Global Value Chains, Relatedness, Economic Upgrading, EU regions

1 Introduction

Nowadays, widening income disparities and increasing inequalities across and within regions in the EU represent a challenging topic for researchers and policymakers alike (Feldman et al. 2021). For long, researchers have addressed this issue, by investigating the reasons of these territorial imbalances, by underling the importance of knowledge, among other factors, in triggering economic development, from Hayek (1945) onward.

The literature of Evolutionary Economic Geography proposed that regional capabilities enhance the ability of a region to develop new activities and upgrade existing activities. Indeed, building on the principle of relatedness (Boschma 2017; Hidalgo et al. 2018), studies show that some regions have many capabilities to do so, while other regions have fewer opportunities, depending on their levels of development. High-income regions tend to host a wide range of capabilities that gives them lots of opportunities to develop new activities related to their existing activities, while low-income regions have a much narrower set of capabilities, giving them fewer opportunities to move into related activities (Hidalgo et al. 2007). Pinheiro et al. (2021) show these diversification opportunities in high-income regions are in more complex, sophisticated activities, while such opportunities in low-income regions are restricted to less complex activities. As high-complex activities tend to bring higher economic benefits than low-complex activities (Hidalgo and Hausmann 2009; Mewes and Broekel 2020; Pintar and Scherngell 2020; Davies and Maré 2021; Rigby et al. 2022), this is likely to result in widening income disparities across regions (Pinheiro et al. 2021).

However, this literature on relatedness, complexity and regional diversification has not taken into account the role of inter-regional linkages (Boschma and Iammarino 2009; Balland and Boschma 2021), let alone the role of GVCs for providing new opportunities for regions (Boschma 2022). GVCs participation represents not only flows of goods and services but can also act as a source of external knowledge for regions (Morrison et al., 2008, 2013; Lema et al., 2019). The benefits from participating in GVCs get higher when this participation moves to higher value-added sectors of GVCs (Gereffi et al., 2011), triggering an economic upgrading process (Giuliani et al., 2005; Gereffi, 2019). Recent literature explores this connection, such as assessing the impact of GVCs participation on productivity of countries (Pahl et al., 2020). To our knowledge, there exists no study to date that has brought together the two literatures and investigated the impact of GVC participation on economic complexity of regions.

The objectives of the paper are as follows. First, we assess the effect of GVC participation on economic complexity of 236 NUTS-2 regions in Europe covering a period of 11 years (2000-2010). We follow the argument of the Economic Complexity literature (Hidalgo et al. 2009; Hausmann et al. 2011) that differentiates economic activities according to their level of sophistication or complexity. We test whether GVC participation enhances the capacity of regions to produce more sophisticated and complex products. Second, we test whether this effect of GVC participation still holds when including the role of regional capabilities. For instance, Balland et al. (2019) argued that regions need absorptive capacity to move into more complex activities and upgrade their existing activities. Indeed, they showed that regions with higher relatedness density are more capable of moving into more complex activities. This implies that not all regions may be able to gain – in terms of production sophistication – from participation in GVCs to the same extent. Third, we test whether this effect of GVC participation differs between regions. We expect low-complex regions to face more restrictions to upgrade their economies, while high-complex regions have sophisticated structures and skills that permit them to participate in higher value-added GVCs (Gereffi et al., 2011).

The paper aims to contribute to the literature in a number of ways. First, we connect the literature on Economic Complexity to the GVC literature, by coupling the concept of upgrading with the complexity of activities, and looking at the importance of external linkages through GVCs for the economic complexity of regions. Second, we embed this complexity approach on GVC in an evolutionary framework, by assessing the relative importance of local capabilities and GVC participation for regional complexity, and how these are inter-related. Third, we follow recurrent calls from scholars (e.g. MacKinnon 2012; Yeung 2021; Boschma 2022) to link more tightly Evolutionary Economic Geography to the study of GVC. And fourth, we investigate the sectoral and regional specificities of such relationships, and apply that to a comparative study of European regions.

This work is structured as follows. In Section 2, we discuss our theoretical framework and present our hypotheses. Section 3 presents the data and clarifies the methodology. Section 4 present the main findings. Section 5 concludes.

2 Literature Review

The GVC literature has made key contributions to explain the capacity of countries and firms to develop new value chains, or to upgrade within existing value chains. Studies have focused on identifying opportunities for local producers to learn from global leaders in value chains (Gereffi 1999; Humphrey and Schmitz 2002), and how global linkages foster upgrading in clusters (Guerrieri et al. 2001; Giuliani et al. 2005; Pietrobelli and Rabellotti 2007, 2011).

The main focus of attention has been on upgrading along the vertical dimension (from low to high value-added activities along the same VC), rather than the horizontal dimension (chain or inter-sectoral upgrading, where firms move into new but often related industries, Gereffi and Fernandez-Stark 2011) where the meaning of upgrading is not always immediately clear (Boschma 2022). The economic complexity literature (Hidalgo and Hausmann 2009; Hausmann et al. 2014) has made efforts to differentiate products in terms of their complexity. According to Hidalgo and Hausmann (2009), complexity captures the difficulty of mastering capabilities that are required to excel in a product or service. This is reflected by the non-ubiquity of the product on the one hand, and the diversity of capabilities that need to be brought together and coordinated to produce such product on the other hand. Advanced products demand a diverse set of expertise which requires strong coordination capabilities. Horizontal upgrading can then be reconceptualized with the introduction of a new product in a country that is more complex than the average complexity of all its existing products.[1]

There has been little interaction between the GVC and Complexity literatures. To integrate the concepts of upgrading and complexity and to apply it to the study of GVC might be a first step. A next step is to account for the role of GVC participation in enhancing economic complexity in countries (Cheng et al. 2015). GVC participation is conceived to give regions access to knowledge and information (Morrison et al., 2008, 2013; Lema et al., 2019). Morrison et al. (2008) argued that GVCs promote knowledge exchange between territories and thus represent a potential knowledge-channel that transfers capabilities across space (Pietrobelli et al., 2011). Nowadays, GVCs constitute a substantial part of global innovation networks and may contribute to cross-border innovation (Pietrobelli, 2022). This may trigger a process of knowledge accumulation, innovation and economic upgrading in regions (Giuliani et al., 2005;

[1] We acknowledge though that the GVC literature has often considered various modes of upgrading, including for example process upgrading, i.e. higher productivity in producing the same goods, or product upgrading (Humphrey and Schmitz 2002, Gereffi 2019)

Gereffi et al. 2011; Jurowetzki et al., 2018; Fagerberg et al., 2018; Lee et al., 2018; Lema et al. 2018; Gereffi, 2019). However, there is little understanding of the effect of GVC participation on the economic complexity of regions, and under what conditions this holds.

But not only external linkages through GVCs may be important for the economies of regions to upgrade and achieve higher levels of complexity. The literature on Evolutionary Economic Geography (Boschma and Frenken 2006; Martin and Sunley 2006) has shed light on the importance of local capabilities for the ability of a region to upgrade their economies, and how it might be highly dependent on the stage of development (Van Dam et al. 2020). Capabilities are embodied in economic activities (such as products or industries) that consist of specific sets of knowledge, skills and institutions that activities need as inputs for their production. Some activities share similar capabilities, while other activities do not. This is captured by the concept of relatedness (Breschi et al. 2003; Hausmann et al. 2007; Hidalgo et al. 2007; Boschma 2017; Hidalgo et al. 2018). Some regions are specialized in activities that are closely related to each other (their structure shows high coherence), while other regions are specialized in activities that are related to a lesser extent (the composition of their economies is more fragmented, with a lower average relatedness). Relatedness also turns out to be a relevant indicator to identify diversification potentials of regions (Neffke et al. 2011; Balland et al. 2019). The higher the average relatedness of local activities, the more spillovers across local activities, the more diversification opportunities regions have (Frenken et al. 2007). What is more, hosting a high variety of closely related activities (high relatedness density) makes regions also more capable of moving into complex products (Balland, 2016). Balland et al. (2019) showed it is difficult for regions to diversify into more complex activities, unless these are related to local activities. That is, every region has the ambition to move into highly complex technologies like Artificial Intelligence, but very few regions have the capacity to do so. Thus, regional capabilities may matter for regions to develop complex activities, but systematic empirical evidence is still lacking.

To our knowledge, no study yet exists that has estimated the relative importance of such regional capabilities and GVC participation for regional complexity. We formulate the following hypothesis:

H1: Relatedness density and GVC participation enhance the economic complexity of regions

However, we also expect differences across regions. Not all regions may have the same capacity to benefit from GVC participation and increase the complexity of their economies. Likewise, not all firms may have such capabilities, and therefore benefit from integration into GVCs (Morrison et al., 2008). Complex activities tend to be spatially concentrated and sticky, that is, they do not move easily across space. Studies show that very few regions specialize in high-complex activities while many regions focus on low-complex activities (Balland and Rigby 2017; Balland et al. 2020; Mewes and Broekel 2020; Davies and Maré 2021). Moreover, external knowledge is not exploitable by all GVCs participants: the learning process is facilitated when the territories have some characteristics such as a strong scientific and educational infrastructure (Crescenzi et al., 2014) and sophisticated levels of knowledge (Boschma and Iammarino 2009; Rodrik, 2018). Pinheiro et al. (2021) explored the diversification potentials of regions with varying complexity levels. What they found is that many low-complex regions have diversification potentials primarily in low-complex activities, while high-complex regions have diversification potentials primarily in high-complex activities. This implies low-complex regions may be trapped in 'low complexity' economies, as they will have a hard time to diversify into high-complex activities. The only way out is to make a sort of jump which is unlikely to happen as local capabilities are not of immediate relevance. By contrast, high-complex regions are not trapped: they can diversify more easily in complex activities, as their existing capabilities allow them to do so.

So, when regions host complex activities, their sophisticated structure makes it easier to exploit information from external sources through their GVC participation. Participation in GVC makes possible knowledge transfers, and the best receivers are the territories with an already good level of industrial sophistication. Therefore, we formulate the following hypothesis:

H2: GVC participation enhances the economic complexity in high-complex regions more than in low-complex regions

Regions with scant complexity rely on a productive structure of low-sophisticated goods and services. According to hypothesis 2, this lack of sophisticated capabilities does not facilitate the exploitation of external knowledge to move them into complex activities. This implies that low-complex regions can only benefit from GVC participation when they possess the absorptive capacity in terms of relatedness to do so. This leads to the following hypothesis.

H3: GVC participation has a positive effect on economic complexity in low-complex regions with higher levels of relatedness density

3 Data and methods

To test our hypotheses, we rely on a recent dataset for regional participation in GVCs[2] for the period 2000-2010 and for 14 sectors.[3] We computed measures of Economic Complexity and Relatedness Density by using employment data (extracted from Eurostat: Structural Business Statistics[4]) for the time span 2000-2010 and for 54 sectors. We explain the method used in what follows.

3.1 Global Value Chains participation (GVCs index)

A key challenge is to compute the regional and sectoral GVCs participation's indexes for EU regions, as data on EU regional trade are scant. We rely on recently released IO tables (Thissen et al., 2018) that include information about trade data for EU NUTS-2 regions for the period 2000-2010, which are the most recent available[5]. We follow the literature (Borin et al., 2017; Borin et al., 2019) and calculate the GVC index as the ratio of the backward and forward components on Gross Export, for each region *r* and year *t*, as shown in Equation 1. The backward component represents the foreign value added content of exports, while the forward component stands for the domestic value added sent to third economies[6].

$$1)\quad GVC\_index_{r,t} = \frac{GVC\_backward_{r,t} + GVC\_forward_{r,t}}{Gross\ Exports_{r,t}}$$

The sectoral participation is computed by measuring the ratio of the sectoral backward and forward component on sectoral exports. We also compute the participation indexes for two

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[2] We calculate the GVCs participation indexes by using the "Regional IO tables" (Thissen et al., 2018)

[3] Later we test the models on two different samples, manufacturing and tradable goods, for the purpose of checking robustness. We report further information about the composition of sectors in the Appendix (A.1).

[4] Following RAMON (Eurostat), we match Structural Business Statistics data (Eurostat) for the period 2000-2007 (Nace Rev.1.1) with those of the period 2008-2010 (Nace Rev. 2.2). A partial loss of information is due to a number of unmatchable sectors.

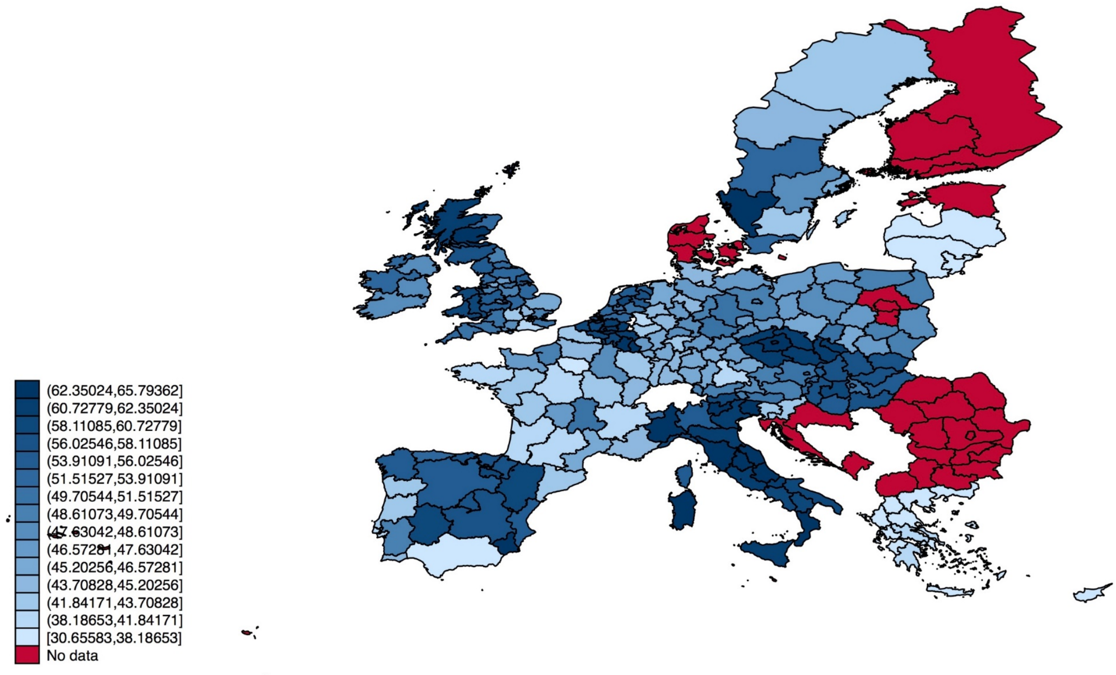
[5] We calculated the index of participation by using the '*icio*' Stata-command (Belotti et al., 2020) that is based on an implemented value-added decomposition (Borin et al., 2017).

[6] We present their mathematical definitions in the Appendix (A.2).

macro-sectors: manufacturing and tradable. These participation indexes represent the average level of integration in GVCs for each EU region and in each sector.

Figure 1 shows the geographical distribution of GVC participation in Europe, as an average over the period 2000-2010. The map suggests that there is lots of heterogeneity in GVCs participation across EU regions. Broadly speaking, GVC integration is high in countries like Hungary, the Czech Republic, Slovakia, Belgium, the Netherlands, Italy and large parts of Spain, while countries like Greece, the Baltic states, France, and Poland, show lower levels.

Figure 1. GVC participation in EU regions, as average for period 2000-2010



Source: Authors' elaboration. Missing data in red

3.2 Relatedness Density

To capture the role of regional capabilities, we follow the relatedness literature in calculating a Relatedness Density measure that requires two steps (Hidalgo et al. 2007; Boschma et al., 2015; Balland et al. 2019).

First, we determine the degree of Relatedness ϕ between 54 industries, including 26 non-tradable sectors, making use of sectoral employment data, and using the EconGeo R-package

(Balland, 2017). We organized the data in 6 sum-matrices, one for each 2-years temporal window, from *2000-2001* to *2010-2011*, that include *r* regions in rows and *s* sectors in columns. As shown in Equation 2, we count the times that two sectors, s_1 and s_2, occur together (∧) in the same region *r*. We successively divide this number by the times that this co-occurrence happens in all the regions (R).

$$2) \quad \phi_{r,t} = \frac{(s_1 \wedge s_2)_r}{(s_1 \wedge s_2)_R}$$

Second, we regionalize the data by computing a Relatedness Density measure that sums all the relatedness values of those sectors that are related to sector *s*, and in which region *r* has a Revealed Comparative Advantage (RCA) higher than 1. RCAs are measured based on employment shares for each period *t*, as in Equation 3, following Balassa (1965):

$$3) \quad RCA_{r,s,t} = \frac{Emp_{r,s,t}/\Sigma_s Emp_{r,s,t}}{\Sigma_r Emp_{r,s,t}/\Sigma_r \Sigma_s Emp_{r,s,t}}$$

Finally, we compute our Relatedness Density, in which x_s takes a value of 1 when the sectoral RCAs are higher than 1, and 0 otherwise.

$$4) \quad Relatedness\ Density_{r,s,t} = \frac{\Sigma_s x_s \phi_{r,t}}{\Sigma_s \phi_{r,t}}$$

We compute the measure of Relatedness Density for all European regions, for the period 2001-2011. The map is shown in Appendix A3. Relatedness Density scores are high in many capital regions in Europe, confirming other studies (Balland et al., 2019). Some regions also tend to score high on average, like in Germany, Spain and Northern Italy. Especially Eastern Europe tends to score relatively low, as well as Sweden.

3.3 Economic Complexity

As discussed above, we need to measure the levels of sophistication or complexity for all sectors in order to determine the levels of Economic Complexity in all EU regions. To compute this variable we rely on the concept of Economic Complexity, as an index of the rarity of knowledge and the diversity of knowledge that production in a sector requires. Hidalgo et al. (2009) show how this index embodies the complexity of economic output, by measuring the sophistication of export products. Balland et al. (2017) and Balland et al. (2019) adapt this measure to assess the level of complexity of technologies, by using patent data.

We make use of the employment data of 54 sectors in order to determine the regional level of economic complexity. The index of Economic Complexity is determined by the combination of different elements of sectoral knowledge required to produce a good.

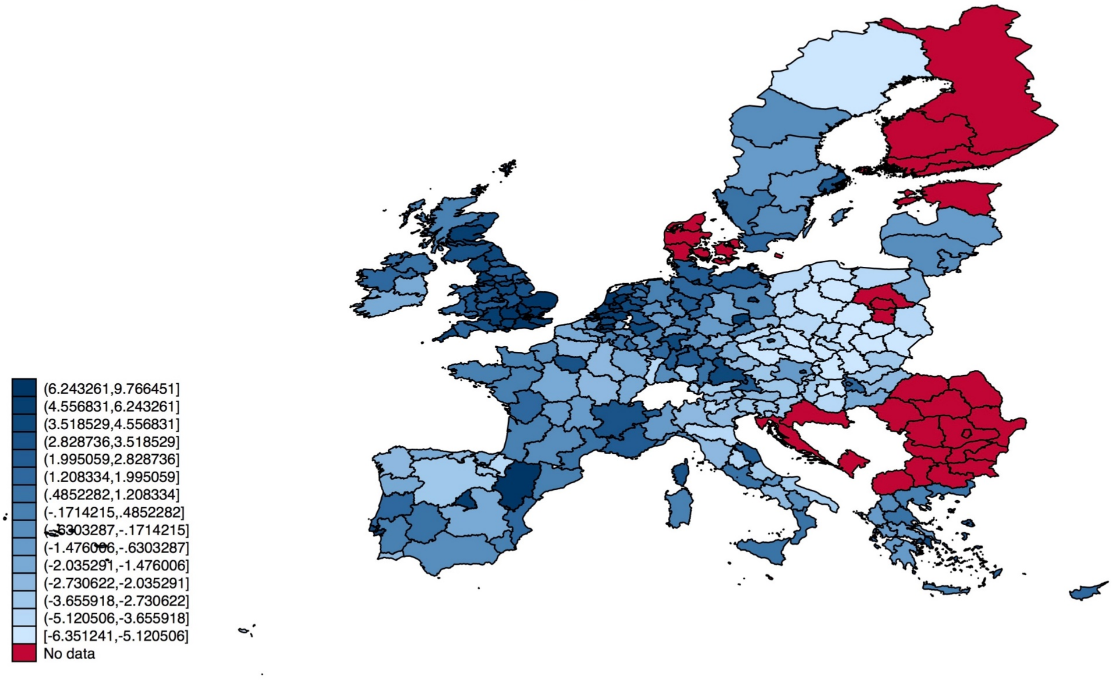
We construct one sum-matrix for the period 2000-2010, of dimension $r*s$, where r is the number of regions and s the sector of employment. Following the method of reflection (Hidalgo et al., 2009) by using EconGeo (Balland, 2017), we compute a binary-valued matrix M of RCA (Balassa, 1965), as in Equation 3. We standardize the matrix M along its transpose (M^T), resulting in a product square matrix $B = M^T * M$, equal to the number of sectors. Economic Complexity is the standardized difference between the second eigenvector ($\vec{K}$) of matrix B and its average, as shown in Equation 5:

$$5)\quad ECI_r = \frac{\vec{K} - \langle\vec{K}\rangle}{stdev(\vec{K})}$$

As result, we have the average Economic Complexity for each region r, for the whole period. We created time series, following the temporal distribution of the employment. Then, we multiplied the Economic Complexity of each region by its yearly employment share, resulting in an annual-index of Economic Complexity for the time span 2000-2010. We followed the same procedure for computing the same variable for manufacturing and tradable sectors, by including only the sector of interest in the sum-matrix.

Figure 2 shows the spatial pattern of Economic Complexity in Europe. As expected, capital regions in Europe such as Rome, Amsterdam, Brussels, Madrid and Inner London tend to show high levels of complexity. Many regions in countries like the Netherlands and the UK, and some regions in Germany and Spain score high. Eastern European countries score low on this complexity index, as well as some regions in Italy, for instance.

Figure 2. Economic Complexity in EU regions, average for period 2000-2010



Source: Authors' elaboration. Missing data in red

3.4 Descriptive statistics

The descriptive statistics of all variables are summarized in Table 1. *N* represents the number of regions and *T* the years. It is worth highlighting that a few regions are not included in the analysis: this is the case for NUTS-0 observations, as in Bulgaria, Finland and Denmark. This loss of observations is due to the lack of coherence between the SBS database, Eurostat, and the IO tables. Indeed, the IO tables are based on the NUTS-2010 classification, while the other tables are based on the 2013 nomenclatures. To make them comparable, we relied on RAMON (Eurostat). As shown in Table 1, the Economic Complexity computed on manufacturing sectors includes only 20 classes, so it suffers from the small size of the sum-matrix. For this reason, these results should be treated with caution.[7]

The statistical distribution of our variables is represented in the following Table 1:

Table 1 – Descriptive Statistics

Variable (log of mean centred values)	Number of sectors (unit)	Mean	Std. Dev.	Min	Max	Observations
*Complexity (*1000)*	54 (number)					
overall		-.0050126	3.52015	-6.974428	10.43611	N = 2591

[7] Therefore, the regression table using these data are reported in Appendix A.4.

between			3.522991	-6.626954	9.635526	n = 238
within			.1615852	-1.34121	1.226393	T = 10.8866
*Complexity in manufacturing sectors (*1000)*	20 (number)					
overall		-.8791615	152.7021	-510.2881	356.08	N = 2591
between			153.9575	-479.1226	338.0672	n = 238
within			7.079309	-51.74917	54.31984	T = 10.8866
*Complexity in tradable sectors (*1000)*	28 (number)					
overall		-.0041003	1.388814	-2.036615	4.142385	N = 2591
between			1.389649	-1.942706	4.035931	n = 238
within			.0594609	-.6075548	.392536	T = 10.8866
Relatedness Density	54 (number)					
overall		3.17e-09	.9145434	- 3.521007	2.752146	N = 2447
between			.9039682	-3.399536	2.542639	n = 236
within			.1805824	-1.606601	.9541558	T = 10.3686
GVCs index	14 (percentage)					
overall		1.40e-09	.1647723	-.6043179	.3449566	N = 2447
between			.1626298	-.4875925	.2776896	n = 236
within			.03694	-.6583172	.1502511	T = 10.3686
GVCs index (manufacturing sectors)	5 (percentage)					
overall		-7.76e-10	.130642	-.5906224	.2780879	N = 2596
between			.1248086	-.3678099	.2553042	n = 236
within			.039372	-.4771767	.2265841	T = 11
GVCs index (tradable sectors)	8 (percentage)					
overall		-1.40e-09	.1642021	-.6541388	.3659505	N = 2596
between			.1597632	-.5177278	.2909052	n = 236
Within			.039197	-.5692132	.1746633	T = 11
GDP p.c.	14 (Million euro pc)					
overall		-3.30e-09	.54626	-1.949807	1.615054	N = 2447
between			.5380179	-1.466291	1.412707	n = 236
Within			.1236228	-.6610161	.6082767	T = 10.3686

3.5 Empirical Strategy

The aim of this paper is to analyse the impact of Relatedness Density and GVC participation on the Economic Complexity of 236 NUTS2 regions in Europe. We estimated OLS regressions using regional fixed effects (μ_r), to control for unobserved regional heterogeneity. Variables have been transformed in logarithmic and mean centred values, to mitigate hypothetical heteroskedasticity, and to assess the percentage change of our dependent variable due to a unit increase in the independent variables. We also lagged the explanatory variables by one year *t*, to avoid some endogeneity issues, and we clustered the standard errors at the regional level.

To test Hypothesis 1, we estimated the single and joint effects of GVC participation (GVC) and Relatedness Density (REL) on the Economic Complexity (ECI) of regions *r* in Europe in each year *t* for the period 2000-2010, controlling for GDP per capita, as shown in Model 1:

1) $$ECI_{r,t} = \beta_0 + \beta_1 ln(GVC_{r,t-1}) + \beta_2 \ln(REL_{r,t-1}) + \beta_3 \left(ln\left(GVC_{r,t-1}\right) * ln\left(REL_{r,t-1}\right)\right) + \beta_4 \, ln\left(GDPpc_{r,t-1}\right) + \mu_r + \varepsilon_r$$

To test Hypothesis 2, we split the sample into two with respect to the Economic Complexity levels of the NUTS2 regions. In Model 2, we first analyzed the first quartile (IQ) of regions in terms of their scores on Economic Complexity, i.e. we only include the 25% least-complex regions (*nc*):

2) $$ECI_{nc,t} = \beta_0 + \beta_1 ln(GVC_{nc,t-1}) + \beta_2 \ln(REL_{nc,t-1}) + \beta_3 \, ln\left(GDPpc_{nc,t-1}\right) + \mu_{nc} + \varepsilon_{nc}$$

Then, we include the interaction term to this latter, as in equation 1. Moreover, we employed the same method by selecting the last quartile (IVQ) of the EU regions in terms of their Economic Complexity (the 25% most Complex regions (*c*)). Thus, we check the robustness of our results making the same estimations for a sample of the 50% most complex regions and a sample of the 50% least complex regions. These results are shown in Table 4 (models 6-9).

Finally, we repeated the same analyses for tradable sectors only. The results are presented in Table 5. Here, the objective is to test the robustness of the impact of Relatedness Density and GVC integration on Economic Complexity. We focus only on the tradable sectors because these are more likely to be characterized by a form of organization like a GVC.

4 Results

Table 2 presents the main results. Model 1 shows the full sample. While we would have expected a positive association between GVC participation, Relatedness Density and Economic Complexity of regions (hypothesis 1), the results show a negative and significant coefficient of GVC participation and a non-significant coefficient of Relatedness Density. The interaction term is positive and significant though, meaning that an increase in Relatedness Density increases the effect of GVC participation on Economic Complexity.

When we split the sample in low and high-complex regions, the results change dramatically. In Models 2 and 3, we present the outcomes for the 25% least complex regions. We find that both GVC participation and Relatedness Density impact negatively on the Economic Complexity of these regions. These results show that lower instead of higher levels of GVC participation and lower instead of higher levels of Relatedness Density are associated with higher levels of Economic Complexity in low-complex regions. However, when including the interaction term in Model 3, the R^2 improves slightly (37,6%), the negative signs of the coefficients of both variables remain, and the interaction term turns positive and significant. This appears to indicate that for increasing values of Relatedness Density, the GVC participation impacts positively and significantly on the Economic Complexity of low-complex regions.

Models 4 and 5 show the same analyses but only for the sample of the 25% most complex regions. Compared to the low-complex regions, the results change completely. Both GVC participation and (to a lesser extent) Relatedness Density tend to foster Economic Complexity in high-complex regions. Adding the interaction term in Model 5 shows that the effect of GVC participation on Economic Complexity is enhanced with higher values of Relatedness Density.

Table 2. Estimations for full sample and sub-samples of low- and high-complex regions

	Dependent variable: *Economic Complexity* (ECI)[8]				
	(1)	(2)	(3)	(4)	(5)
Variables (t-1, log and mean centred)	Full sample	25% low complex	25% low complex with interaction	25% most complex	25% most complex with interaction
GVC index	-0.333**	-1.946***	-1.837***	1.149***	0.849**
	(0.0198)	(8.20e-05)	(0.000110)	(0.00379)	(0.0232)
Relatedness Density	0.0400	-0.173**	-0.308***	0.131	0.150**
	(0.201)	(0.0386)	(0.00196)	(0.113)	(0.0419)
GVC index** Relatedness Density	0.281***		1.599***		0.596***
	(0.00234)		(0.000707)		(0.000344)
GDP p.c.	-0.150**	-0.379***	-0.380***	0.913***	0.917***
	(0.0330)	(0.000129)	(0.000136)	(4.13e-05)	(3.68e-05)
Constant	0.0744***	-4.440***	-4.463***	4.358***	4.374***
	(0)	(0)	(0)	(0)	(0)
Observations	2,420	595	595	615	615
R-squared	0.023	0.333	0.376	0.270	0.285

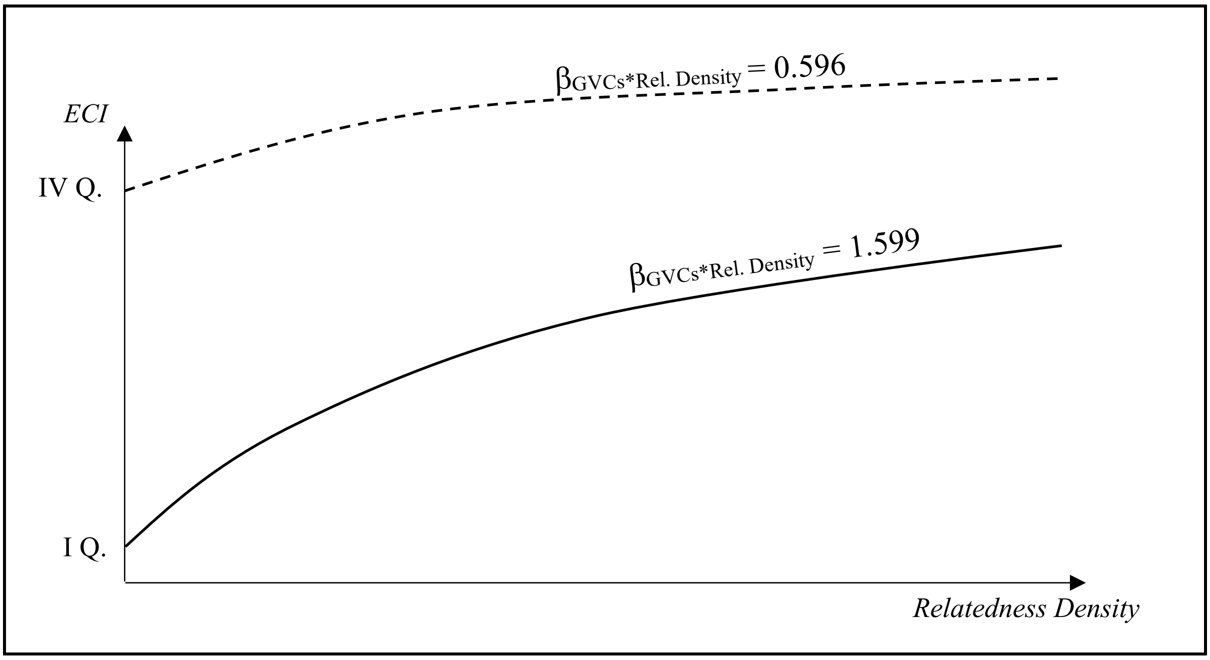
[8] We multiply ECI*1000, in all the tables (3,4,5,6), in order to facilitate the reading of the results.

Number of regions	236	60	60	61	61
Standard Errors (cluster)	Regions	Regions	Regions	Regions	Regions
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Subsamples have been defined as 25% most and least complex regions.

In sum, we find partial support for hypothesis 1. For the full sample of regions, GVC participation and Relatedness Density do not enhance separately Economic Complexity, but their interaction effect is positive and significant. We do find strong support for hypothesis 2, showing a fundamental difference between low- and high-complex regions. GVC participation and Relatedness Density enhance the Economic Complexity of high complex regions, but not so in low-complex regions. We also find support for hypothesis 3. Indeed, it seems that the effect of GVC participation is stronger with increasing Relatedness Density in low-complex regions, as compared to high-complex regions. Looking at the coefficients of the interaction terms in Model 3 and 5 of Table 2, we observe that the coefficient is almost 3 times bigger (*1,599*) in low-complex regions (IQ) than in high-complex regions (IVQ) (*0,596*). This is further illustrated in Figure 4.

Figure 4. The effect of interaction terms on ECI for low-complex and high-complex regions



Notes: Subsamples have been defined as 25% most and least complex regions, I quantile and IV quantile respectively

As a robustness check, we extended our sample selection by making a group of the 50% least complex and the 50% most complex regions. Table 3 shows the findings remain the same as in Table 2. It confirms earlier results that in low-complex regions, GVC participation takes a positive role only with increasing levels of Relatedness Density, while in high-complex regions, both GVC participation and Relatedness Density independently have a positive effect.

Table 3. Estimations for full sample and sub-samples of low- and high-complex regions

	Dependent variable: *Economic Complexity* (ECI)				
	(1)	(6)	(7)	(8)	(9)
Variables (t-1, log and mean centred)	Full sample	50% low complex	50% low complex with interaction	50% most complex	50% most complex with interaction
GVCs index	-0.333**	-0.864***	-0.882***	0.452***	0.392**
	(0.0198)	(0.000762)	(9.78e-05)	(0.00129)	(0.0226)
Relatedness Density	0.0400	-0.0917**	-0.109**	0.102**	0.110***
	(0.201)	(0.0471)	(0.0323)	(0.0107)	(0.00477)
GVCs index** Relatedness Density	0.281***		0.516***		0.191*
	(0.00234)		(0.00867)		(0.0848)
GDP p.c.	-0.150**	-0.383***	-0.395***	0.515***	0.506***
	(0.0330)	(2.14e-07)	(2.19e-07)	(4.71e-06)	(7.83e-06)
Constant	0.0744***	-3.052***	-3.061***	2.686***	2.690***
	(0)	(0)	(0)	(0)	(0)
Observations	2,420	1,145	1,145	1,275	1,275
R-squared	0.023	0.254	0.269	0.170	0.174
Number of regions	236	112	112	124	124
Standard Errors (cluster)	Regions	Regions	Regions	Regions	Regions
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Subsamples have been defined as 25% most and least complex regions.

Finally, as a further robustness test, we did the same analyses only for tradable sectors, as these are the sectors that are more likely adopting a GVC-like form of industrial organization. Table 4 reports the findings. First, Relatedness Density has no negative effects anymore: when significant, its impact is positive. Second, the coefficient of GVC participation remains negative and significant in low-complex regions and positive and significant in high-complex regions. Third, when we introduce the interaction terms, we note that the coefficient is positive and significant in low-complex regions (model 3) but it is not anymore significant in high-complex regions (model 5). Again, this tends to confirm hypothesis 3. In Appendix A5, we show the results for the tradable sectors by considering also the 50% least complex and 50% most complex regions. All results remain the same, except for the interaction term for high-complex regions, which not only turns positive and significant again, but the coefficient is also stronger than the one for low-complex regions.

Table 4. Estimations for full sample and sub-samples, only for tradable sectors

	Dep. variable: *Economic Complexity computed on tradable sectors* (ECI)				
	(1)	(2)	(3)	(4)	(5)
Variables (t-1, log and mean centred)	Full sample	25% low complex	25% low complex with interaction	25% most complex	25% most complex with interaction
GVCs index – tradable sectors	-0.0301	-0.445***	-0.382***	0.730***	0.644***
	(0.471)	(5.97e-06)	(0.000299)	(3.03e-05)	(0.000523)
Relatedness Density	0.0219*	-0.0188	-0.0355	0.0718**	0.0690**
	(0.0605)	(0.436)	(0.168)	(0.0362)	(0.0477)
GVCs index trad. ** Relatedness Density	0.0732**		0.255**		0.178
	(0.0300)		(0.0285)		(0.255)
GDP p.c.	-0.0146	-0.113***	-0.119***	0.350***	0.356***
	(0.551)	(0.000629)	(0.000425)	(0.000103)	(7.13e-05)
Constant	0.0137***	-1.468***	-1.476***	1.898***	1.905***
	(0)	(0)	(0)	(0)	(0)
Observations	2,420	551	551	551	551
R-squared	0.008	0.309	0.334	0.293	0.298
Number of regions	236	59	59	62	62
Standard Errors (cluster)	Regions	Regions	Regions	Regions	Regions
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Subsamples have been defined as 25% most and least complex regions.

6 Conclusions

The aim of the paper was to assess the effects of GVC participation and Relatedness Density on the Economic Complexity of regions in Europe, and whether these effects differ across regions. We find that not all regions benefit from GVCs in the same manner: it is important to make a distinction between low-complex and high-complex regions. Low-complex regions do not benefit from GVC participation unless their regional capabilities (in terms of Relatedness Density) are stronger. In other words, GVC participation fosters economic complexity in low-complex regions only with increasing values of Relatedness Density. In contrast, in high-complex regions, GVC participation enhances on its own the complexity of their economies, and this effect becomes even stronger the higher the Relatedness Density in the regions. Consistently, this interaction effect is less strong for high-complex than for low-complex regions.

The paper contributes to different literatures. It shows how fruitful it can be to make connections between the GVC and the Economic Complexity literatures, which only few papers have done so far. The study shows that the effect of GVC participation differs between economies with different levels of economic complexity. The paper also contributes to the literature on Economic Complexity by showing how levels of economic complexity may be affected by external linkages such as GVCs. The paper also adds to the Evolutionary Economic Geography, which has been reluctant to take on board GVCs as an object of study, despite a few exceptions (see Boschma 2022). The study shows that the impact of GVC participation cannot be analysed in isolation, leaving out the role of regional capabilities (Boschma 2017). This is in line with Kano et al. (2020) – and with the earlier contributions of Pietrobelli and Rabellotti (2007) – who argued that the GVC literature should investigate more thoroughly the interplay between local capabilities and inter-regional linkages. Our findings tend to support this, showing that GVC participation is only beneficial in low-complex regions when relatedness density is stronger.

It goes without saying that the paper also has limitations that need to be taken up in future research. First, we looked at the heterogeneity of regions in terms of low and high-complexity only, but there may be other characteristics that might influence the effect of GVC participation on regional complexity, such as for example institutions and innovation systems (Pietrobelli and Rabellotti, 2011). Second, we did not investigate whether low-complex regions are indeed trapped in a low-complex economy, as suggested, and how and to what extent GVC participation, and other factors, could contribute to escaping such a trap. Third, a key finding was that in low-complex regions, GVC participation fosters the process of economic upgrading only for increasing values of Relatedness Density. We have to develop more understanding of which local capabilities, and through which mechanisms, this economic upgrading process may work out. Fourth, the paper opens up questions on what policies should be developed to make GVC participation more beneficial in low-complex regions – increasing GVC integration will certainly not be sufficient in these contexts - (Pietrobelli et al, 2021), how to tackle income disparities in Europe in Cohesion policy from such a GVC perspective, and how GVC participation could contribute to convergence processes in Europe (Comotti et al. 2020).

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Appendix

A.1 Manufacturing and Tradable sectors

In computing the tradable and manufacturing groups, we consider the following classification for the first one (^{T}) and the second (^{M}), both by excluding non-tradable sectors (^{NT}).

#	$^{(category)}$ **ID sector - description**
1	$^{(T)}$ CA - Mining and quarrying of energy producing materials
2	$^{(T)}$ CB - Mining and quarrying except of energy producing materials
3	$^{(T, M)}$ DA15 - Manufacture of food products and beverages
4	$^{(T, M)}$ DA16 - Manufacture of tobacco products
5	$^{(T, M)}$ DB17 - Manufacture of textiles
6	$^{(T, M)}$ DB18 - Manufacture of wearing apparel; dressing; dyeing of fur
7	$^{(T, M)}$ DC19 - Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
8	$^{(T, M)}$ DD20 - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
9	$^{(T, M)}$ DE21 - Manufacture of pulp, paper and paper products
10	$^{(T, M)}$ DE22 - Publishing, printing and reproduction of recorded media
11	$^{(T, M)}$ DF23 - Manufacture of coke, refined petroleum products and nuclear fuel
12	$^{(T, M)}$ DG24 - Manufacture of chemicals and chemical products
13	$^{(T, M)}$ DH25 - Manufacture of rubber and plastic products

14	(T, M) DI26 - Manufacture of other non-metallic mineral products
15	(T, M) DJ27 - Manufacture of basic metals
16	(T, M) DJ28 - Manufacture of fabricated metal products, except machinery and equipment
17	(T, M) DK29 - Manufacture of machinery and equipment n.e.c.
18	(T, M) DL30 - Manufacture of office machinery and computers
19	(T, M) DL31 - Manufacture of electrical machinery and apparatus n.e.c.
20	(T, M) DM34 - Manufacture of motor vehicles, trailers and semi-trailers
21	(T, M) DM35 - Manufacture of other transport equipment
22	(T, M) DN36 - Manufacture of furniture; manufacturing n.e.c.
23	(T) E - Electricity, gas and water supply
24	(NT) F45 – Construction
25	(NT) G501 - Sale of motor vehicles
26	(NT) G502 - Maintenance and repair of motor vehicles
27	(NT) G503 - Sale of motor vehicle parts and accessories
28	(NT) G504 - Sale, maintenance and repair of motorcycles and related parts and accessories
29	(NT) G505 - Retail sale of automotive fuel
30	(NT) G511 - Wholesale on a fee or contract basis
31	(NT) G512 - Wholesale of agricultural raw materials and live animals
32	(NT) G513 - Wholesale of food, beverages and tobacco
33	(NT) G514 - Wholesale of household goods
34	(NT) G515 - Wholesale of non-agricultural intermediate products, waste and scrap
35	(NT) G518 - Wholesale of machinery, equipment and supplies
36	(NT) G519 - Other wholesale
37	(NT) G521 - Retail sale in non-specialized stores
38	(NT) G522 - Retail sale of food, beverages and tobacco in specialized stores
39	(NT) G523 - Retail sale of pharmaceutical and medical goods, cosmetic and toilet articles
40	(NT) G524 - Other retail sale of new goods in specialized stores
41	(NT) G525 - Retail sale of second-hand goods in stores
42	(NT) G526 - Retail sale not in stores
43	(NT) G527 - Repair of personal and household goods
44	(NT) H55 - Hotels and restaurants
45	(NT) I60 - Land transport; transport via pipelines
46	(NT) I61 - Water transport

47	(NT) I62 - Air transport
48	(NT) I63 - Supporting and auxiliary transport activities; activities of travel agencies
49	(NT) I64 - Post and telecommunications
50	(T) K70 - Real estate activities
51	(T) K71 - Renting of machinery and equipment without operator and of personal and household goods
52	(T) K72 - Computer and related activities
53	(T) K73 - Research and development
54	(T) K74 - Other business activities

A.2 Backward and Forward components

In the GVCs equation (1), the Backward component represents the foreign value added content of exports (%):

$$GVC\_backward_r = \frac{V_r(I - A_{rr})^{-1}[\sum_{j\neq r}^{G} A_{rj}B_{jr}E_{rs} + \sum_{t\neq r}^{G} V_t B_{tr}E_{rs}]}{u_n E_{rs}}$$

Instead, the Forward component embodies the domestic value added sent to third economies:

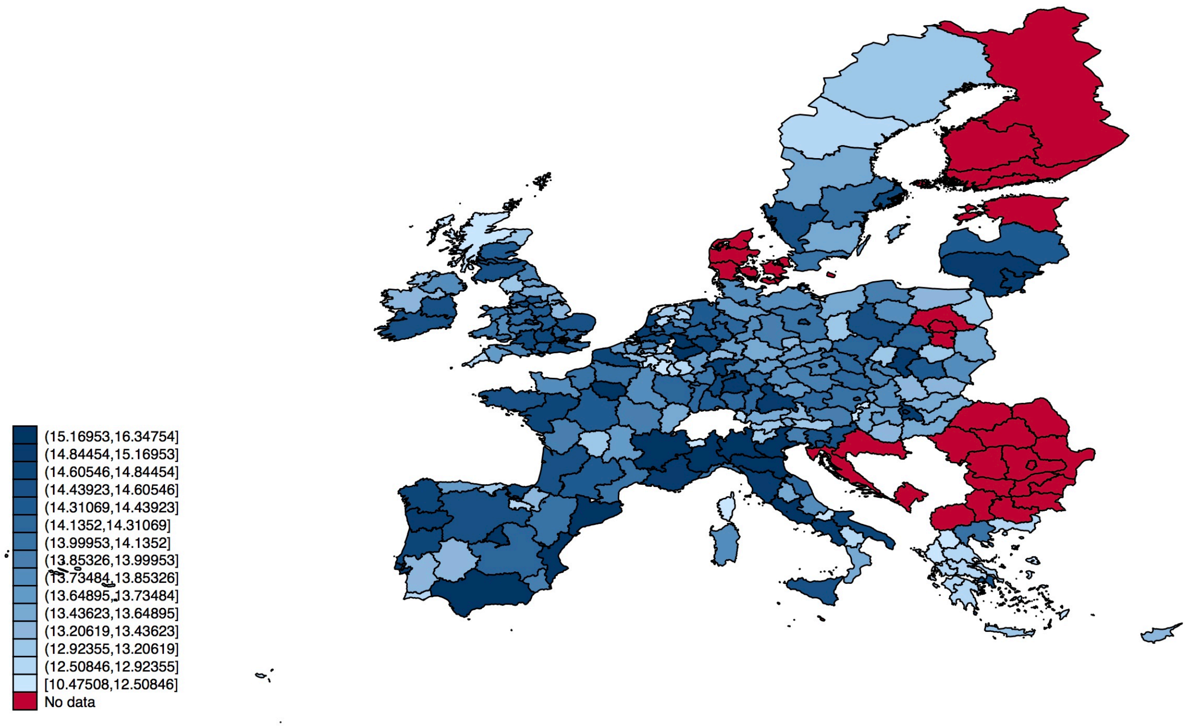
$$GVCforward_r = \frac{V_r(I - A_{rr})^{-1}A_{rs}(I - A_{ss})^{-1}\left[\sum_{j\neq s,r}^{G} Y_{sj} + \sum_{j\neq s}^{G} A_{sj}\sum_{l\neq r,s}^{G} B_{js}Y_{sl}\right]}{u_n E_{rs}}$$

Where, with the same notation employed by Borin et al. (2017):

- V_r: value added shared from the region *r*;
- $(I - A_{rr})^{-1}$: Leontief inverse, that indicates the amount of input that needs the region *r* to produce an additional unit of the good for the same region in this case; If there was *rs* as subscript, it indicates the amount of input that needs the region *r* to produce an additional unit of the good for the generic region *s*;

- $B_{jr} = (I - A_{jr})^{-1}$;
- E_{rs}: export from the region *r* to the region generic *s*;
- Y_{rs}: final goods from the region *r* consumed in region generic *s*.

A.3 Relatedness Density in EU regions, average for the period 2000-2010 (missed data in red, authors' elaboration).



A.4 Estimation results for manufacturing sectors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sub-model	Full sample	25% low complex	25% low complex with interaction	25% most complex	25% most complex with interaction	50% low complex	50% low complex with interaction	50% most complex	50% most complex with interaction

Variables (t-1, log and mean centred)	Dependent variable: *Economic Complexity in manufacturing sectors (*1000)*								
GVCs index – manufacturing sectors	11.23	-39.09***	-50.20***	68.78***	85.61***	-31.29***	-34.46***	65.44***	71.45***
	(0.102)	(0.00552)	(0.00372)	(0.00844)	(4.18e-05)	(0.000315)	(4.47e-05)	(2.81e-07)	(1.54e-09)
Relatedness Density	0.476	-24.94***	-27.13***	1.578	0.901	-11.05***	-11.15***	3.634***	3.279**
	(0.740)	(0.00412)	(0.00156)	(0.562)	(0.706)	(0.000875)	(0.000835)	(0.00268)	(0.0106)
GVCs index man. ** Relatedness Density	8.279		-15.01*		-28.42		-5.142		-12.73
	(0.112)		(0.0967)		(0.139)		(0.299)		(0.111)
GDP p.c.	-1.226	-8.970	-6.175	28.31***	26.42***	-8.776*	-8.258*	10.77***	10.80***
	(0.655)	(0.366)	(0.522)	(0.00223)	(0.00218)	(0.0611)	(0.0695)	(0.000421)	(0.000303)
Constant	3.121***	-218.5***	-216.9***	179.5***	180.2***	-128.7***	-128.6***	121.4***	121.3***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Observations	2,420	551	551	551	551	1,182	1,182	1,238	1,238
R-squared	0.006	0.187	0.197	0.509	0.517	0.130	0.131	0.400	0.405
Number of regions	236	60	60	61	61	119	119	121	121
Standard Errors (cluster)	Regions	Regions	Regions	Regions	Regions	Regions	Regions	Regions	Regions
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

A.5 Estimations for full sample and sub-samples of low- and high-complex regions (50-50), only for tradable sectors

	Dependent variable: *Economic Complexity computed on tradable sectors* (ECI)				
	(1)	(6)	(7)	(8)	(9)
Variables (t-1, log and mean centred)	Full sample	50% low complex	50% low complex with interaction	50% most complex	50% most complex with interaction
GVCs index – tradable sectors	-0.0301	-0.207***	-0.203***	0.374***	0.348***
	(0.471)	(2.79e-06)	(3.78e-08)	(2.05e-05)	(3.70e-05)

Relatedness Density	0.0219*	-0.0237*	-0.0269**	0.0473***	0.0516***
	(0.0605)	(0.0551)	(0.0323)	(0.00440)	(0.000927)
GVCs index trad. ** Relatedness Density	**0.0732****		**0.103*****		**0.163*****
	(0.0300)		(0.00643)		(0.00532)
GDP p.c.	-0.0146	-0.104***	-0.110***	0.217***	0.218***
	(0.551)	(1.09e-06)	(6.22e-07)	(1.40e-05)	(1.30e-05)
Constant	0.0137***	-1.133***	-1.138***	1.081***	1.084***
	(0)	(0)	(0)	(0)	(0)
Observations	2,420	1,209	1,209	1,084	1,084
R-squared	0.008	0.269	0.285	0.196	0.208
Number of regions	236	119	119	120	120
Standard Errors (cluster)	Regions	Regions	Regions	Regions	Regions
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1