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Abstract

This paper studies technological diversification in European regions incorporating global value chain participation as interregional linkages. The empirical analysis is developed for 243 NUTS-2 European regions between 2000-2010. Results show that, while regional capabilities remain crucial, global value chain participation matters for technological diversification. Particularly, backward participation in global value chains increases the chances of regions to trigger technological diversification. Forward participation in global value chains only increases the likelihood of technological diversification when combined with regional capabilities. Finally, global value chain participation is found to be more relevant for transition regions rather than for less and more developed regions.

JEL classifications: F14, F63, O33, R11, R12

Keywords: Global value chains, technological diversification, backward-forward participation, relatedness, interregional linkages, European regions

1.- INTRODUCTION

Technological diversification in regions remains a central issue within the literature in economic geography (Thwaites, 1978; Rigby and Essletzbichler, 1997; Rodríguez-Pose and Crescenzi, 2008), and especially within evolutionary economic geography (Frenken and Boschma, 2007; Boschma et al., 2015; Balland et al., 2019). However, it has been traditionally approached with a strong focus on the role of regional capabilities (Storper, 1993; Amin and Thrift, 1994; Asheim, 1996). While the literature has shown how regional capabilities influence the evolution of regions' technological specialisations, recent claims have highlighted the need to further include interregional linkages to better understand regional technological diversification (Asheim and Isaksen, 2002; Trippl et al., 2018; Yeung, 2021, 2024; Boschma, 2022, 2024; Giustolisi et al., 2023).

In this vein, scholars have studied how international and interregional linkages matter for technological catch-up, knowledge spillovers, and economic upgrading. The literature has identified different channels through which these dynamics occur: MNEs (Cantwell and Iammarino, 2000, 2005; Iammarino and McCann, 2013; Crescenzi et al., 2014, 2015; Elekes et al., 2019), FDI (Crescenzi and Iammarino, 2017; Iammarino, 2018), high-skilled migrants (Breschi et al., 2017, 2020), inventors' collaborations (Breschi and Lissoni, 2009; Miguelez and Moreno, 2013, 2018; Hesse and Fornahl, 2020), and global value chains (GVCs) (Gereffi, 1994, 1999; Giuliani et al., 2005; Pietrobelli and Rabellotti, 2007, 2011; Morrison et al., 2008; De Marchi et al., 2018; Crescenzi and Harman, 2023).

However, while these contributions have provided crucial insides about the role of interregional linkages, few attempts have been made to integrate them in evolutionary models of technological diversification (Balland and Boschma, 2021; Miguelez and Morrison, 2022). This paper particularly focuses on the role of global value chain participation as a source of external knowledge to complement regional capabilities (Boschma, 2022, 2024; Frenken et al., 2023). Thus, this paper explores technological diversification in 243 NUTS-2 European regions between the years 2000-2010. The results show that, while regional capabilities remain crucial, overall, total global value chain participation is associated with higher chances of technological diversification. On the one hand, backward global value chain participation generally contributes to higher likelihood of technological diversification. On the other hand, forward global value chain participation only increases the likelihood of technological diversification when it is combined with regional capabilities. Furthermore, global value chain participation is found to be more important for transition regions than for less and more developed regions.

Therefore, the contributions of this paper are several. First, this paper shows how global value chain participation can be integrated in evolutionary models of technological diversification. This helps to further bridge the literatures in GVCs and evolutionary economic geography (Trippl et al., 2018; Yeung, 2021, 2024; Boschma, 2022, 2024). Particularly, it does so by building upon the notion of regional capabilities, exploring the relationship between internal and external sources of knowledge (De Propris, 2024; Lee, 2024; Poon, 2024). Second, it develops such analysis at the regional level, which is crucial to better understand globalisation dynamics (Crescenzi and Iammarino, 2017; Iammarino, 2018; Capello and Dellisanti, 2024;

Capello et al., 2024; Fatikhova et al., 2024). Finally, addressing this issue at the regional level contributes to uncover the heterogenous effects that interregional linkages have for technological diversification depending on regions' economic development (Pietrobelli and Rabellotti, 2007; Balland and Boschma, 2021).

The remainder of this paper is structured as follows. Next section covers the relevant literature. Section 3 describes the data and variables used in the empirical analysis. Section 4 introduces the empirical framework. Section 5 presents the results. Section 6 concludes and discusses policy implications.

2.- TECHNOLOGICAL DIVERSIFICATION AND GLOBAL VALUE CHAINS

There is an extensive literature in evolutionary economic geography covering regional technological diversification (Boschma et al., 2015; Rigby, 2015; Balland et al., 2019). This literature has mainly focused on how regional capabilities shape the evolution of regions' technological specialisations. However, recent calls have asked to incorporate interregional linkages, such as global value chains, as a source of non-local knowledge for regions (Trippl et al., 2018; Yeung, 2021, 2024; Boschma, 2022, 2024). This paper takes up this challenge.

Therefore, there have been substantial contributions highlighting how regional capabilities shape technological diversification in regions. Particularly, related diversification has been found to be the norm in regional diversification, meaning that regions tend to diversify into related economic activities (Hidalgo et al., 2007; Neffke et al., 2011; Boschma et al., 2015; Rigby, 2015; Hidalgo et al., 2018; Farinha et al., 2019). However, these evolutionary models of technological diversification overlooked the importance of non-local sources of knowledge complementing regional capabilities (Bunnell and Coe, 2001; Bathelt et al., 2004; Trippl et al., 2018; Giustolisi et al., 2023). This contrasts with seminal contributions in the field that repeatedly called for the inclusion of external linkages to overcome path-dependence and enhance regional new path-creation and diversification (Martin and Sunley, 2006; Boschma, 2017).

Thus, this has encouraged scholars to extend the evolutionary models of regional diversification and to include interregional linkages. In this vein, Bathelt et al. (2004), Boschma (2005), Morrison et al. (2013), Balland and Boschma (2021), highlighted that interregional linkages represent a way to prevent regional lock-ins. Furthermore, interregional linkages also contribute to avoid development and low-complexity traps (Diemer et al., 2022, Pinheiro et al., 2022; Balland and Boschma, 2024). Indeed, knowledge flows are crucial to strengthen the innovative capacity of regions by recombining knowledge coming from different places (Paci and Usai, 2009; Marrocu et al., 2013; De Noni et al., 2017). Just recently, some contributions have started to use economic complexity and relatedness metrics on value added data to explore the relevance of global value chains from an evolutionary perspective (Koch, 2021; Hernández-Rodríguez et al., 2023; Sebestyén et al., 2024).

However, while still underexplored in evolutionary economic geography, the literature in global value chains have underlined how value chains act as a source of exogenous knowledge

(Humphrey and Schmitz, 2002; Pietrobelli and Rabellotti, 2007, 2011; Morrison et al., 2008; Ponte and Sturgeon, 2014). This is especially relevant explaining how participation in global value chains contribute to trigger knowledge exchange and spur innovation (Gereffi, 1994, 1999; Gereffi and Kaplinsky, 2001; Humphrey and Schmitz, 2002; Giuliani et al., 2005). This literature in global value chains has also underlined the importance of local capabilities to ensure the absorptive capacity of regions as the assimilation and appropriation of external knowledge (Cohen and Levinthal, 1990).

Indeed, in order to absorb and benefit from global value chain linkages, regional capabilities and institutions play a crucial role (Frenken et al., 2023). Frenken et al. (2007) point out that knowledge will spillover when there are shared competencies as related variety. This is in line with Boschma and Iammarino (2009) when they find that related variety contributes to regional economic growth regarding trade linkages in Italy. As argued by De Noni et al. (2017), following Asheim et al. (2011), the more diversified a region is, the better, because diversity triggers new ideas and induces knowledge spillovers that are essential for innovation. Similarly, Coe et al. (2004), and Coe and Yeung (2015), argued that strategic coupling and anchoring for regions is crucial to leverage interregional capabilities, and ultimately push regional economic development.

Subsequently, regions can incorporate non-local sources of knowledge to acquire new technological capabilities and complement those they already have. Regions that are engaged and participate in global value chains are more exposed to this non-local knowledge, increasing their chances of technological diversification. Also, when this exposure towards exogenous knowledge is combined with related capabilities, the absorption of new knowledge is expected to be easier, contributing to even a higher likelihood of technological diversification. This leads to formulate the following hypothesis.

Hypothesis 1a: Global value chain participation increases the likelihood of technological diversification in regions.

Hypothesis 1b: Global value chain participation further increases the likelihood of technological diversification in regions when it is combined with related regional capabilities.

Thus, the capacity of regions to connect between them is what shapes the regional chain of skills, capabilities, and functions in value chains (Crescenzi et al., 2014; Crescenzi and Iammarino, 2017; Bontadini et al., 2024). This turns into a conceptualisation of innovation systems in which relevant knowledge resources are not just generated within regions, but they are also incorporated throughout external inputs (Ascani et al., 2020). Nevertheless, Boschma (2004) criticised that the literature did not always explicitly state what particular kinds of interregional linkages matter. In this vein, the literature in global value chains, has recently emphasised the importance of both backward and forward linkages for knowledge transfer and absorption (Tajoli and Felice, 2018; Savona and Bontadini, 2023; Bontadini et al., 2024). Indeed, as argued by Iammarino (2018), international and interregional flows take two ways: inward and outward, and both represent different opportunities and challenges for regions in terms of learning and innovation.

On the one hand, around the idea of "*learning by importing*", some contributions highlighted that it is through importing and recombining inputs coming from different regions what trigger the acquisition and absorption of technological capabilities and new knowledge (Grossman and Helpman, 1991, 1993; Dollar et al., 1988; Keller, 2004). At the regional level, Andersson et al. (2013) found empirical evidence on the positive relationship between high-quality imports and the renewal of regional exports. They highlight that it's the connection via imports to international markets, and its combination with strong local milieu, that represents a stimulus for the renewal of regional exports. This supports the idea that imported knowledge from abroad can spillover towards local firms, turning knowledge flows into innovations. Furthermore, this positive effect of backward global value chain participation is expected to be reinforced under the presence of existing regional capabilities. The existence of regional related capabilities contribute to a higher regional absorptive capacity, facilitating the absorption of new knowledge and technological diversification (Cohen and Levinthal, 1990). Thus, the following hypotheses are stated.

Hypothesis 2a: Backward global value chain participation increases the likelihood of technological diversification in regions.

Hypothesis 2b: Backward global value chain participation further increases the likelihood of technological diversification in regions when it is combined with related regional capabilities.

On the other hand, the literature on trade and innovation has also studied knowledge spillovers though exporting: "*learning by exporting*". This refers to the ability of firms to innovate and enhance their productivity after entering exporting markets (Loecker, 2013). Salomon and Shaver (2005) particularly found that the benefits of entering exporting markets come in terms of innovation, as shown in their empirical analysis of Spanish manufacturing firms. Also, at the firm level, Ivarsson and Alvstam (2011) found that IKEA's suppliers use IKEA's technological support to improve their operational, duplicative, and adaptive and innovative capabilities. Mazzi et al. (2024) found that there is a positive relationship between GVC participation and the development of technological capabilities, particularly from learning by exporting, using data for Soutth-Africa. Then, Buciuni and Finotto (2016) highlighted the importance of geographical proximity and production functions in supply relationships across value chains for innovation capabilities. Again, this process of knowledge diffusion through forward linkages can be boosted by the existence of regional capabilities: when the production of value added for GVCs builds upon existing related regional capabilities, higher probability of knowledge diffusion and technological diversification arise. The following hypotheses are stated.

Hypothesis 3a: Forward global value chain participation increases the likelihood of technological diversification in regions.

Hypothesis 3b: Forward global value chain participation further increases the likelihood of technological diversification in regions when it is combined with related regional capabilities.

Finally, the literature has also pointed out that interregional linkages, particularly, global value chains, benefit differently less developed and more developed regions. In this vein, Giuliani et al. (2005), and Pietrobelli and Rabellotti (2007), has provided sound evidence on how global value chains are beneficial for Latin American countries. Based on this work, Morrison et al. (2008), and Pietrobelli and Rabellotti (2011), furtherly theorised how global value chains can engage with innovation systems offering learning opportunities for developing countries. In the European regional context, Balland and Boschma (2021) found that, as suggested by Fitjar and Rodríguez-Pose (2011), and Grillitsch and Nilsson (2015), interregional linkages, as inventors' collaborations, were more important for technological diversification in peripheral regions.

Therefore, developed regions have already strong technological capabilities upon which trigger technological diversification (Pinheiro et al., 2022). On the contrary, developing regions can access new knowledge from GVCs that helps them to overcome the lack of regional capabilities, fostering technological diversification (Frenken et al., 2023). Thus, external knowledge derived from GVCs can be more relevant for developing regions than for developed regions. However, it is also important to acknowledge that the benefits for less developed regions can be limited by gatekeepers and power asymmetries (Morrison, 2008; Dallas et al., 2019). Then, the following hypotheses are formulated.

Hypothesis 4a: Backward and forward global value chain participation are more relevant for increasing the likelihood of technological diversification in less developed regions than in developed regions.

Hypothesis 4b: Backward and forward global value chain participation further increase the likelihood of technological diversification in less developed regions when they are combined with related regional capabilities.

3.- DATA AND VARIABLES

3.1.- DATA

For the purposes of the empirical analysis two different datasets are used. In the first place, to map the technological portfolios of regions and their evolution over time, patent data is used. This paper uses OECD-REGPAT[1], which includes information regarding patent applications between the years 1977 and 2021 (Maraut et al., 2008). The patent applications are regionalised into NUTS-2 using the inventors' addresses and assigned to technological domains using the International Patent Classification (IPC) at 4-digits level.

In the second place, to compute the regional participation in global value chains, EUREGIO interregional input-output tables are used. EUREGIO includes data on input-output flows for 249 regions from 24 European countries, 16 non-EU countries, a rest of the world section, and 14 industries, between the years 2000-2010 (Thissen et al., 2018). Thus, although the coverage of OECD-REGPAT includes all OECD Member States, this paper just focuses on 243 European regions (23 EU countries and the UK) due to data availability in EUREGIO.[2]

Finally, data for the control variables at the regional level, namely GDP per capita, population density, number of patent applications, and human capital is drawn from Eurostat publicly available datasets. Data for the UK regions was retrieved from the UK Office for National Statistics.

3.2.- REGIONAL TECHNOLOGICAL SPECIALISATION

In order to analyse the evolution of the technological capabilities of regions, it is required to map their technological portfolios in different moments of time. Following previous literature in the field (Boschma et al., 2015; Balland et al., 2019), and using patent data, particularly fractional counts of patents, Revealed Technological Advantages (RTAs) are computed. The RTAs are computed as Revealed Comparative Advantages (RCAs) (Balassa, 1965). The RTAs are mathematically formulated as follows:

$$RTA_{r,i,t} = 1 \; if \; \frac{Patents_{r,i,t} \big/ \sum_i Patents_{r,i,t}}{\sum_r Patents_{r,i,t} \big/ \sum_r \sum_i Patents_{r,i,t}} \geq 1 \quad (1)$$

$$RTA_{r,i,t} = 0 \; if \; \frac{Patents_{r,i,t} \big/ \sum_i Patents_{r,i,t}}{\sum_r Patents_{r,i,t} \big/ \sum_r \sum_i Patents_{r,i,t}} < 1 \quad (2)$$

Thus, a certain region *r* will have an RTA in a certain technology class *i* and in a certain time period *t*, when the share of patents in that region in that technology and in that time period is higher or equal to the same share in the whole Europe. Notice that the RTA is therefore a binary version of the RCAs previously mentioned. Thus, when a certain region exhibits an RTA equal to 1 in a certain technology class, the region will be considered to be specialised in that technology.

Subsequently, by examining the changes in the RTAs by time periods, it will be possible to observe the technological diversification of regions over time. When a certain region *r* becomes specialised in a certain technology class *i*, in which it was not specialised in the previous period *t-1*, the region will be considered to enter a new technology, thus experiencing technological diversification. This can be mathematically formulated as follows:

$$Entry_{r,i,t} = 1 \; if \; RTA_{r,i,t} \geq 1 \; and \; RTA_{r,i,t-1} < 1 \quad (3)$$

$$Entry_{r,i,t} = 0 \; if \; RTA_{r,i,t} < 1 \; and \; RTA_{r,i,t-1} < 1 \quad (4)$$

Notice that when a region is already specialised in a certain technology class, in the next time period, it cannot enter that technology. Furthermore, in order to avoid inconsistent and volatile variations in the RTAs around the threshold, four different time periods are considered: 2000-2001, 2002-2004, 2005-2007, and 2008-2010.

3.3.- TECHNOLOGICAL RELATEDNESS DENSITY

To capture the importance of regional technological capabilities, metrics of relatedness density are computed using patent data (Hidalgo et al., 2007). In the first place, the relatedness between technological classes is obtained. The relatedness between two technological classes *i* and *j* in period *t* is the minimum of the pairwise conditional probabilities of a region having an RTA in a technological class given it has an RTA in another technological class in period *t*. This can be mathematically formulated as follows:

$$Relatedness_{i,j,t} = \min\{P(RTA_{i,t} = 1 | RTA_{j,t} = 1), P(RTA_{j,t} = 1 | RTA_{i,t} = 1)\} \quad (5)$$

In the second place, following Hidalgo et al. (2007) the relatedness density is be obtained for each region *r* and technology class *i* at time *t* by adding all the relatedness values of the technologies that are related to technology class i_j, and in which region *r* exhibits an RTA equal to 1. Again, this can be mathematically formulated as follows:

$$Relatedness\ density_{r,i,t} = \frac{\sum_i x_{r,i,t}\phi_{i_j,i_g,t}}{\sum_i \phi_{i_j,i_g,t}} \quad (6)$$

Notice that parameter $x_{r,i,t}$ is a dummy variable with value 1 when the RTA of a technology class *i* in region *r* at time *t* is equal to 1, and 0 otherwise. Thus, the relatedness density is calculated for each region and technology for the considered time windows (2000-2001, 2002-2004, 2005-2007, and 2008-2010).

3.4.- GLOBAL VALUE CHAIN PARTICIPATION

There are several ways of measuring global value chain engagement but in this case, a global value chain participation index is used (Kowalski et al., 2015). This total global value chain participation index captures the origin of the value added in relation to the gross exports of regions. Although the literature has shown several ways of computing global value chain participation indexes, in this paper, the measure proposed by Koopman et al. (2010), based on the seminal work by Hummels et al. (2001), is used. This global value chain participation index takes the following mathematical form:

$$Total\ GVC\ Participation_{r,t} = \frac{FVA_{r,t}}{E_{r,t}} + \frac{REDVA_{r,t}}{E_{r,t}} \quad (7)$$

where *FVA* stands for the foreign content in the gross exports by the region, *REDVA* stands for the value added by the region contained in foreign region's gross exports, so the re-exported domestic value added, and *E* stands for the region's gross exports. Thus, this metric can furtherly be split into two sub-measures: backward and forward global value chain participation. Therefore, while the sum of the two factors contained in the equation (7) gives the total global value chain participation, the first factor (*FVA/E*) represents the backward global value chain participation, and the second one (*REDVA/E*), the forward global value chain participation. It is important to notice that the global value chain participation indexes are computed on a yearly basis using EUREGIO and then averaged for the previously considered time windows (2000-2001, 2002-2004, 2005-2007, and 2008-2010).[3]

4.- EMPIRICAL FRAMEWORK

This section presents the econometric model used in the empirical analysis. Since the purpose of this paper is twofold, two different specifications are required. In order to understand what is the role of interregional value chain linkages, measured by the total global value chain participation of regions, and what are the differences between backward and forward global value chain participation, two-way fixed-effects (region-technology and time fixed-effects) entry models are used. Thus, in these models the dependent variable is the entry of a region in a new technological field, as explained in the previous section. The main variables of interest are the technological relatedness density, the total global value chain participation (8), and the backward, and the forward global value chain participation (9). The baseline models can be mathematically defined as follows:

$$Entry_{r,i,t} = \alpha + \beta_1\, Rel\ Den_{\ r,i,t-1} + \beta_2\, Total\ Part_{\ r,t-1} + \theta\, X_{\ r,t-1} + \delta_{r,i} + \varphi_t + \varepsilon_{r,i,t} \quad (8)$$

$$Entry_{r,i,t} = \alpha + \beta_1\, Rel\ Den_{\ r,i,t-1} + \beta_2\, Back\ Part_{\ r,t-1} + \beta_3\ For\ Part_{\ r,t-1} + \theta\, X_{\ r,t-1} + \delta_{r,i} + \varphi_t + \varepsilon_{r,i,t} \quad (9)$$

Furthermore, these models are extended by including the interaction between the relatedness density and the global value chain participation (total, backward and forward) (10, 11 and 12). Such models are defined as follows:

$$Entry_{r,i,t} = \alpha + \beta_1\, Rel\ Den_{\ r,i,t-1} + \beta_2\, Total\ Part_{\ r,t-1} + \beta_3\, Rel\ Den_{\ r,i,t-1} * Total\ Part_{\ r,t-1} + \theta\, X_{\ r,t-1} + \delta_{r,i} + \varphi_t + \varepsilon_{r,i,t} \quad (10)$$

$$Entry_{r,i,t} = \alpha + \beta_1\, Rel\ Den_{\ r,i,t-1} + \beta_2\, Back\ Part_{\ r,t-1} + \beta_3\, Rel\ Den_{\ r,i,t-1} * Back\ Part_{\ r,t-1} + \beta_4\ For\ Part_{\ r,t-1} + \theta\, X_{\ r,t-1} + \delta_{r,i} + \varphi_t + \varepsilon_{r,i,t} \quad (11)$$

$$Entry_{r,i,t} = \alpha + \beta_1\, Rel\ Den_{\ r,i,t-1} + \beta_2\, For\ Part_{\ r,t-1} + \beta_3\, Rel\ Den_{\ r,i,t-1} * For\ Part_{\ r,t-1} + \beta_4\ Back\ Part_{\ r,t-1} + \theta\, X_{\ r,t-1} + \delta_{r,i} + \varphi_t + \varepsilon_{r,i,t} \quad (12)$$

Notice that since the dependent variable is a dummy variable (entry), these are two-way fixed effects linear probability models (LPMs) in which $X_{r,t-1}$ stands for a vector of control variables at a regional level, $\delta_{r,i}$ and φ_t for region-technology and time fixed effects, respectively, and $\varepsilon_{r,i,t}$ for the regression residual.[4] Again, it is important to underline that while the entry and relatedness density variables are region-technology specific, global value chain participation metrics are at the regional level due to data constraints. Control variables include GDP per capita, as a proxy for the level of regional economic development, population density, as a proxy for agglomeration economies and measured as population by square kilometer, number of patent applications, as a proxy for regions' technological knowledge stock, and human capital, as a proxy for regional absorptive capacity and measured as the share of population with tertiary education. These control variables are used in their logarithmic form to overcome excessed kurtosis. Since errors are correlated within regions, standard errors are clustered at the regional level. Finally, notice that all independent variables are lagged by one period and mean centred.

5.- RESULTS

5.1.- TECHNOLOGICAL DIVERSIFICATION AND GVC PARTICIPATION

This section presents the main findings from the empirical analysis. Table 1 includes the results for total global value chain participation and relatedness density on technological diversification. As in Model 2, both the total GVC participation and the relatedness density have a positive and significant effect on technological diversification. Particularly, using the coefficients from Model 2, one standard deviation increase in the total GVC participation, and the relatedness density, translate into an increase of 1.4 and 3.2 percentage points in the likelihood of technological diversification, respectively.[5] Thus, both regional capabilities (relatedness density) and non-local capabilities (total GVC participation) contribute to increase the chances of triggering technological diversification in regions. These results are consistent with the previous literature and confirm Hypothesis 1a.

Table 1.- Entry models (LPM) for total global value chain participation

	LPM – Dependent variable: Entry (=1)		
	(1) Baseline	(2) Full model FEs	(3) Interaction
Relatedness density (RD)	0.255***	0.311***	0.310***
	(0.0447)	(0.0462)	(0.0463)
GVC total part. (TGVC)	0.204***	0.184**	0.193***
	(0.0749)	(0.0772)	(0.0718)
RD * TGVC			0.953**
			(0.432)
GDP per capita (log)		-0.0111	-0.00919
		(0.0236)	(0.0224)
Population density (log)		-0.0188	-0.0227
		(0.0578)	(0.0571)
Patents (log)		-0.00954**	-0.00925**
		(0.00386)	(0.00388)
Human capital (log)		-0.0180	-0.0119
		(0.0119)	(0.0118)
Constant	0.0732***	0.0626***	0.0639***
	(0.00195)	(0.00551)	(0.00550)
Observations	342,278	342,278	342,278
Adjusted R^2	0.017	0.017	0.017
Region-Tech FEs	YES	YES	YES
Period FEs	YES	YES	YES

Notes. Coefficients are statistically significant at the * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ level.

Furthermore, there is an interplay between regional capabilities and global value chain participation as shown in Model 3 from Table 1. The coefficient for the interaction between the relatedness density and the total GVC participation is positive and significant.[6] This hints that external sources of knowledge are reinforced when the region already accounts for related technological capabilities upon which trigger the technological diversification. This leads to validate Hypotheses 1b.

However, as previously argued, it is required to disentangle if different forms of value chain participation have different implications for technological diversification. Thus, the total value chain participation is decomposed into backward and forward value chain participation. Table 2 presents the results for the relationship between backward-forward global value chain participation, relatedness density, and technological diversification.

Table 2.- Entry models (LPM) for backward and forward value chain participation

	LPM – Dependent variable: Entry (=1)			
	(1) Baseline	(2) Full model FEs	(3) Backward Interaction	(4) Forward Interaction
Relatedness density (RD)	0.255*** (0.0451)	0.311*** (0.0465)	0.312*** (0.0466)	0.289*** (0.0481)
GVC backward part. (BGVC)	0.199** (0.0777)	0.179** (0.0793)	0.179** (0.0788)	0.176** (0.0759)
GVC forward part. (FGVC)	0.218* (0.114)	0.200* (0.115)	0.198* (0.116)	0.298** (0.117)
RD * BGVC			0.105 (0.447)	
RD * FGVC				2.000*** (0.681)
GDP per capita (log)		-0.0109 (0.0237)	-0.0110 (0.0236)	-0.00509 (0.0229)
Population density (log)		-0.0184 (0.0578)	-0.0185 (0.0578)	-0.0243 (0.0564)
Patents (log)		-0.00954** (0.00387)	-0.00962** (0.00388)	-0.00736* (0.00398)
Human capital (log)		-0.0180 (0.0119)	-0.0177 (0.0118)	-0.0115 (0.0118)
Constant	0.0732*** (0.00202)	0.0627*** (0.00559)	0.0631*** (0.00558)	0.0595*** (0.00566)
Observations	342,278	342,278	342,278	342,278
Adjusted R^2	0.017	0.017	0.017	0.017

Region-Tech FEs	YES	YES	YES	YES
Period FEs	YES	YES	YES	YES

Notes. Coefficients are statistically significant at the * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ level.

On the one hand, backward global value chain participation is always positive and statistically significant across the different specifications (Models 1-4 in Table 2). Particularly, using the coefficient from Model 2, one standard deviation increase in backward GVC participation leads to an increase of 1.4 percentage points in the likelihood of technological diversification. Thus, regions receiving value added produced in third regions and then recombining it to produce their own exports, are more likely to technologically diversify over time. This validates Hypothesis 2a. On the other hand, forward global value chain participation, while always positive across specifications, is not always highly statistically significant. This leads to reject Hypothesis 3a.

However, interestingly, when looking at the interaction between regional capabilities (relatedness density) and non-local knowledge (backward and forward GVC participation) some interesting features arise. The interaction with backward participation (Model 4 in Table 2), although positive, is not significant. Thus, the results for total GVC participation in Model 3 in Table 1 did not directly reflect a relationship between regional capabilities and the absorption of new knowledge. Rather than this, as shown by the interaction with forward participation (Model 5 in Table 2), it appears that the chances of triggering technological diversification are enhanced when the production of domestic value added to be exported to third regions is supported by related regional technological capabilities. In fact, not just the interaction, but also forward GVC participation, became positive and significant under such scenario. From Model 4 in Table 2, one standard deviation increase in forward GVC participation leads to 1.7 percentage points increase in the likelihood of technological diversification. Thus, this rejects Hypothesis 2b and validates Hypothesis 3b.[7] Finally, it is worth mentioning that the relatedness density is always positively and significantly associated with technological diversification, even when differentiating between backward and forward GVC participation (Models 1-4 in Table 2).

5.2.- HETEROGENEITY: REGIONAL ECONOMIC DEVELOPMENT

The results provided in the previous section showed how regional global value chain participation act as a source of non-local capabilities, and contributes, along with the existing regional related technological capabilities, to trigger technological diversification. However, as discussed in the literature, the importance of non-local sources of knowledge is expected be more relevant for less developed regions than for developed regions (Giuliani et al., 2005; Pietrobelli and Rabellotti, 2007, 2011; Morrison et al., 2008; Balland and Boschma, 2021).

Therefore, the same empirical analysis is carried out differentiating regions by their level of economic developed. The same econometric models are used in three subsets of the sample: less developed regions, transition regions and developed regions. To group the regions into these categories, the same criteria used for the EU Cohesion Policy at that time was followed. First, regions with a GDP per capita lower than the 75% of the EU average were categorised as less developed regions. Second, regions with a GDP per capita between the 75% and the 90% of the EU average were categorised as transition regions. Third, regions with a GDP per capita higher than the 90% of the EU average were categorised as more developed regions.[8]

The results show that transition regions benefit the most from GVC participation.[9] The results obtained for the transition regions' subsample follow a similar pattern than the results presented above. In transition regions, backward global value chain participation is the main channel enhancing the chances to trigger technological diversification (Models 4-7 in appendix X). Interestingly, also the interaction between backward participation and relatedness density is positive and significant, while the effect for forward participation and its interaction vanish (Models 6-7 in appendix X). This points towards the fact that transition regions are in an intermediate development stage in which they are able to absorb external sources of knowledge based on their existing related technological capabilities. This is in line with Balland and Boschma (2024), who recently found that transition regions are usually stuck in low relatedness density and complexity traps. This may be due to heterogeneities in their industrial structures and the different relevance of manufacturing and services industries (Baldwin et al., 2024). Thus, global value chain participation can be crucial to promote regional diversification and avoid such lock-ins and development traps in transition regions.

On the contrary, for both less and more developed regions, the effects of global value chain participation (total, backward and forward) fade away. Indeed, the only significant effect that can be observed is due to the interaction between forward GVC participation and the relatedness density. Then, not all regions benefit in the same way from being engaged in global value chains: it appears that for both less developed and more developed regions, the chances of triggering technological diversification increase when promoting the domestic production of value added to be built upon their existing related technological capabilities. All these findings partially support Hypotheses 4a and 4b, since it is just transition regions, and not less and more developed regions, who benefits the most from global value chain participation.

6.- CONCLUSIONS

There is a long-lasting tradition within economic geography and, particularly within evolutionary economic geography, studying regional technological diversification (Thwaites, 1978; Rigby and Essletzbichler, 1997; Boschma et al., 2015; Balland et al., 2019). However, while this evolutionary approach to technological diversification in regions has mainly focused on regional capabilities, the interregional dimension has remained somehow underexplored (Trippl et al., 2018; Balland and Boschma, 2021; Miguelez and Morrison, 2022). This paper argues that the evolutionary understanding of technological diversification in regions can benefit from the inclusion of interregional linkages such as global value chains (Gereffi, 1994; Yeung, 2021, 2024). In this vein, the results show that overall, total global value chain participation enhances the chances of technological diversification in regions: regions are more likely to become specialised in a new technological field when they have related regional technological capabilities, and they are engaged in global value chains.

Thus, this paper contributes to the integration of evolutionary economic geography and global value chain literatures (Yeung, 2021, 2024; Rodríguez-Pose, 2021; Boschma, 2022, 2024; Lee, 2024). This paper adopts an evolutionary framework based on the notion of relatedness (Frenken et al., 2007; Neffke et al., 2011; Boschma et al., 2015; Hidalgo et al., 2018) to assess the role of global value chain participation in technological diversification in regions. Furthermore, it distinguishes between different forms of GVC participation, namely backward and forward participation, and the level of economic development of regions. It does so to account for the fact that knowledge flow differently within global value chains (backward and forward), benefiting more some regions than others, particularly those still in development process (Giuliani et al., 2005; Pietrobelli and Rabellotti, 2007, 2011; Morrison et al., 2008; De Marchi et al., 2018; Iammarino, 2018; Savona and Bontadini, 2023).

However, this paper is not without limitations. First, due to data availability, the time period covered by the empirical analysis remains short (2000-2010). Nevertheless, the scarcity of interregional input-output tables at the subnational level prevent for now the extension of the time periods for the analysis (Los et al., 2015; Timmer et al., 2015; Thissen et al., 2018). Second, the industrial aggregation of the EUREGIO data limits the ability to explore technological diversification within specific value chains. Third, the role of regional institutions is not included in this paper (Rodríguez-Pose, 2013).[10] The potential negative consequences, along with the unequal distribution of benefits derived from GVC participation, is likely to be shaped by regional institutions, particularly when it comes to regional innovation capacity (Rodríguez-Pose, 2021; Rodríguez-Pose and Di Cataldo, 2015; Cortinovis et al., 2017).

Finally, the conclusions drawn by this paper have relevant policy implications. The role of interregional linkages, and particularly global value chain participation, is an important dimension that still needs to be included in regional innovation and industrial policies such as Smart Specialisation Strategies (McCann and Ortega-Argilés, 2015; Uyarra et al., 2018; Balland et al., 2019; Giustolisi et al., 2023). While relying on regional capabilities has been proved as crucial to promote technological diversification, this does not prevent benefiting from external non-local knowledge. Thus, regions should engage in global value chains to benefit from non-local knowledge, enhancing their existing technological capabilities and promoting interregional collaborations (De Noni et al., 2017; Bachtrögler-Unger, 2023). Furthermore, policy interventions should differentiate regions according to their level of economic development to ensure that the engagement in GVCs foster the interplay between regional and non-local capabilities. In particular, policies targeting transition regions should leverage on interregional linkages to avoid low-complexity and development traps (Diemer et al., 2022; Pinheiro et al., 2022; Balland and Boschma, 2024).

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NOTES

1.- February 2022 Edition.

2.- Appendix I includes a detailed list of the NUTS-2 regions included in the analysis.

3.- Appendix II includes descriptive statistics. Appendix III includes the correlation matrices.

4.- Similar results were obtained using logit and probit models as in appendixes IV and V.

5.- The effect is computed multiplying the standard deviation of the explanatory variable as included in the model with its coefficient.

6.- Appendix VI includes the marginal effects from the interaction between the GVC participation metrics and the relatedness density.

7.- Appendix VII includes the results using GVC participation metrics restricted to manufacturing and construction industries. Since one concern could be that participation in global value chains related to agriculture and services may not provide technological knowledge to be captured by patents, the analysis is then repeated using GVC participation indicators just for manufacturing and construction industries, in which Van Looy et al. (2014), established a crosswalk between patents IPC codes and NACE codes, implying the existence of patenting activity within those industries. The results hold, and the coefficients become even more statistically significant.

8.- For simplicity, the EU average GDP per capita was computed as the average of all regions included in the whole sample across periods. Appendix VIII includes a map grouping regions into the three categories.

9.- Appendixes IX, X, and XI include the results for the three categories.

10.- Although new data on regional institutions has become available (e.g. Charron et al., 2014), the period of analysis in this paper (2000-2010) is out of the scope of such databases.

REFERENCES

Amin, A., & Thrift, N. J. (1994). Globalisation, institutions and regional development in Europe. *Oxford University Press*.

Andersson, M., Bjerke, L., & Karlsson, C. (2013). Import flows: extraregional linkages stimulating renewal of regional sectors? *Environment and Planning A*, 45(12), 2999-3017.

Ascani, A., Bettarelli, L., Resmini, L., & Balland, P. A. (2020). Global networks, local specialisation and regional patterns of innovation. *Research Policy*, 49(8), 104031.

Asheim, B. T. (1996). Industrial districts as 'learning regions': A condition for prosperity. *European Planning Studies*, 4(4), 379–400.

Asheim, B. T., & Isaksen, A. (2002). Regional innovation systems: the integration of local 'sticky and global 'ubiquitous' knowledge. *The Journal of Technology Transfer*, 27(1), 77-86.

Asheim, B. T., Boschma, R., & Cooke, P. (2011). Constructing regional advantage: Platform policies based on related variety and differentiated knowledge bases. *Regional Studies*, 45(7), 893-904.

Bachtrögler-Unger, J., Balland, P. A., Boschma, R., & Schwab, T. (2023). Technological capabilities and the twin transition in Europe: Opportunities for regional collaboration and economic cohesion.

Balassa, B. (1965). Trade liberalisation and "revealed" comparative advantage. *The Manchester School*, 33(2), 99-123.

Baldwin, R., Freeman, R., & Theodorakopoulos, A. (2024). Deconstructing deglobalization: The future of trade is in intermediate services. *Asian Economic Policy Review*, *19*(1), 18-37.

Balland, P. A., Boschma, R., Crespo, J., & Rigby, D. L. (2019). Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification. *Regional Studies*, 53(9), 1252-1268.

Balland, P. A., & Boschma, R. (2021). Complementary interregional linkages and Smart Specialisation: An empirical study on European regions. *Regional Studies*, 55(6), 1059-1070.

Balland, P. A., & Boschma, R. (2024). *An Evolutionary Approach to Regional Development Traps in European Regions* (No. 2420). Utrecht University, Department of Human Geography and Spatial Planning, Group Economic Geography.

Bathelt, H., Malmberg, A., & Maskell, P. (2004). Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, 28(1), 31-56.

Bontadini, F., Evangelista, R., Meliciani, V., & Savona, M. (2024). Technology, global value chains and functional specialisation in Europe. *Research Policy*, *53*(2), 104908.

Boschma, R. (2004). Competitiveness of regions from an evolutionary perspective. *Regional Studies*, 38(9), 1001-1014.

Boschma, R. (2005). Proximity and innovation: a critical assessment. *Regional Studies*, 39(1), 61-74.

Boschma, R. (2017). Relatedness as driver of regional diversification: A research agenda. *Regional Studies*, 51(3), 351-364.

Boschma, R. (2022). Global value chains from an evolutionary economic geography perspective: a research agenda. *Area Development and Policy*, 7(2), 123-146.

Boschma, R. (2024). An evolutionary approach to regional studies on global value chains. *Regional Studies*, 1-9.

Boschma, R., & Iammarino, S. (2009). Related variety, trade linkages, and regional growth in Italy. *Economic Geography*, 85(3), 289-311.

Boschma, R., Balland, P. A., & Kogler, D. F. (2015). Relatedness and technological change in cities: The rise and fall of technological knowledge in US metropolitan areas from 1981 to 2010. *Industrial and Corporate Change*, 24(1), 223-250.

Breschi, S., & Lissoni, F. (2009). Mobility of skilled workers and co-invention networks: an anatomy of localized knowledge flows. *Journal of Economic Geography*, 9(4), 439-468.

Breschi, S., Lissoni, F., & Miguelez, E. (2017). Foreign-origin inventors in the USA: testing for diaspora and brain gain effects. *Journal of Economic Geography*, 17(5), 1009-1038.

Breschi, S., Lawson, C., Lissoni, F., Morrison, A., & Salter, A. (2020). STEM migration, research, and innovation. *Research Policy*, 49(9), 104070.

Buciuni, G., & Finotto, V. (2016). Innovation in global value chains: Co-location of production and development in Italian low-tech industries. *Regional Studies*, *50*(12), 2010-2023.

Bunnell, T. G., & Coe, N. M. (2001). Spaces and scales of innovation. *Progress in Human Geography*, 25(4), 569-589.

Cantwell, J., & Iammarino, S. (2000). Multinational corporations and the location of technological innovation in the UK regions. *Regional Studies*, 34(4), 317-332.

Cantwell, J., & Iammarino, S. (2005). Multinational corporations and European regional systems of innovation. *Taylor & Francis*.

Capello, R., & Dellisanti, R. (2024). Smile-and-go. Regional performance through global value chains in Europe. *Papers in Regional Science*, *103*(2), 100018.

Capello, R., Dellisanti, R., & Perucca, G. (2024). At the territorial roots of global processes: Heterogeneous modes of regional involvement in Global Value Chains. *Environment and Planning A: Economy and Space*, *56*(3), 833-848.

Charron, N., Dijkstra, L., & Lapuente, V. (2014). Regional governance matters: Quality of government within European Union member states. *Regional Studies*, *48*(1), 68-90.

Coe, N. M., Hess, M., Yeung, H. W. C., Dicken, P., & Henderson, J. (2004). 'Globalizing'regional development: a global production networks perspective. *Transactions of the Institute of British geographers*, 29(4), 468-484.

Coe, N. M., & Yeung, H. W. C. (2015). *Global production networks: Theorizing economic development in an interconnected world*. Oxford University Press.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly,* 128-152.

Cortinovis, N., Xiao, J., Boschma, R., & van Oort, F. G. (2017). Quality of government and social capital as drivers of regional diversification in Europe. *Journal of Economic Geography*, *17*(6), 1179-1208.

Crescenzi, R., Pietrobelli, C., & Rabellotti, R. (2014). Innovation drivers, value chains and the geography of multinational corporations in Europe. *Journal of Economic Geography*, 14(6), 1053-1086.

Crescenzi, R., Gagliardi, L., & Iammarino, S. (2015). Foreign multinationals and domestic innovation: Intra-industry effects and firm heterogeneity. *Research Policy*, 44(3), 596-609.

Crescenzi, R., & Iammarino, S. (2017). Global investments and regional development trajectories: the missing links. *Regional Studies*, 51(1), 97-115.

Crescenzi, R., & Harman, O. (2023). *Harnessing Global Value Chains for regional development: How to upgrade through regional policy, FDI and trade*. Routledge.

Dallas, M. P., Ponte, S., & Sturgeon, T. J. (2019). Power in global value chains. *Review of International Political Economy*, *26*(4), 666-694.

De Noni, I., Ganzaroli, A., & Orsi, L. (2017). The impact of intra-and inter-regional knowledge collaboration and technological variety on the knowledge productivity of European regions. *Technological Forecasting and Social Change*, 117, 108-118.

De Marchi, V., Giuliani, E., & Rabellotti, R. (2018). Do global value chains offer developing countries learning and innovation opportunities?. *The European Journal of Development Research*, 30, 389-407.

De Propris, L. (2024). Globalisation must work for as many regions as possible. *Regional Studies*, 1-4.

Diemer, A., Iammarino, S., Rodríguez-Pose, A., & Storper, M. (2022). The regional development trap in Europe. *Economic Geography*, 98(5), 487-509.

Dollar D., Wolff E. N., Baumol W. J. (1988) The factor-price equalization model and industry labour productivity: an empirical test across countries, in: *Empirical Methods for International Trade,* R. C. Feenstra (Ed.), MIT Press, Cambridge, MA, 23–47.

Elekes, Z., Boschma, R., & Lengyel, B. (2019). Foreign-owned firms as agents of structural change in regions. *Regional Studies*.

Farinha, T., Balland, P. A., Morrison, A., & Boschma, R. (2019). What drives the geography of jobs in the US? Unpacking relatedness. *Industry and Innovation*, 26(9), 988-1022.

Fatikhova, A., Fusillo, F., & Montresor, S. (2024). *Green-tech transition beyond regional borders: the role of embodied green knowledge flows*. Utrecht University, Human Geography and Planning.

Fitjar, R. D., & Rodríguez-Pose, A. (2011). When local interaction does not suffice: sources of firm innovation in urban Norway. *Environment and Planning A*, *43*(6), 1248-1267.

Frenken, K., & Boschma, R. A. (2007). A theoretical framework for evolutionary economic geography: industrial dynamics and urban growth as a branching process. *Journal of Economic Geography*, *7*(5), 635-649.

Frenken, K., Van Oort, F., & Verburg, T. (2007). Related variety, unrelated variety and regional economic growth. *Regional Studies*, 41(5), 685-697.

Frenken, K., Neffke, F., & van Dam, A. (2023). Capabilities, institutions and regional economic development: a proposed synthesis. *Cambridge Journal of Regions, Economy and Society*, rsad021.

Gereffi, G. (1994) The organization of buyer-driven global commodity chains: how US retailers shape overseas production networks, in: G. Gereffi & M. Korzeniewicz (Eds) *Commodity Chains and Global Capitalism* (London: Praeger).

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

Gereffi, G., & Kaplinsky, R. (2001). The value of value chains: spreading the gains from globalisation. *IDS Bulletin*, 32.

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

Giustolisi, A., Benner, M., & Trippl, M. (2023). Smart specialisation strategies: Towards an outward-looking approach. *European Planning Studies*, 31(4), 738-757.

Grillitsch, M., & Nilsson, M. (2015). Innovation in peripheral regions: Do collaborations compensate for a lack of local knowledge spillovers?. *The Annals of Regional Science*, *54*, 299-321.

Grossman, G. M., & Helpman, E. (1991). Trade, knowledge spillovers, and growth. *European Economic Review*, 35(2-3), 517-526.

Grossman, G. M., & Helpman, E. (1993). *Innovation and growth in the global economy*. MIT press.

Hernández-Rodríguez, E., Boschma, R., Morrison, A., & Ye, X. (2023). *Functional upgrading and downgrading in global value chains: evidence from EU regions using a relatedness/complexity framework*. Utrecht University, Human Geography and Planning.

Hesse, K., & Fornahl, D. (2020). Essential ingredients for radical innovations? The role of (un-) related variety and external linkages in Germany. *Papers in Regional Science*, 99(5), 1165-1183.

Hidalgo, C. A., Klinger, B., Barabási, A. L., & Hausmann, R. (2007). The product space conditions the development of nations. *Science*, 317(5837), 482-487.

Hidalgo, C. A., Balland, P. A., Boschma, R., Delgado, M., Feldman, M., Frenken, K., Glaeser, E., He, C., Kogler, D., Morrison, A., Neffke, F., Rigby, D., Stern, S., Zheng, S., & Zhu, S. (2018). The principle of relatedness. *International Conference on Complex Systems* (pp. 451-457).

Hummels, D., Ishii, J., & Yi, K. M. (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics*, 54(1), 75-96.

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

Iammarino, S. (2018). FDI and regional development policy. *Journal of International Business Policy*, 1, 157-183.

Iammarino, S., & McCann, P. (2013). Multinationals and economic geography: Location, technology and innovation. *Edward Elgar Publishing*.

Ivarsson, I., & Alvstam, C. G. (2011). Upgrading in global value-chains: a case study of technology-learning among IKEA-suppliers in China and Southeast Asia. *Journal of Economic Geography*, *11*(4), 731-752.

Keller, W. (2004). International technology diffusion. *Journal of Economic Literature*, 42(3), 752-782.

Koch, P. (2021). Economic complexity and growth: Can value-added exports better explain the link?. *Economics Letters*, *198*, 109682.

Koopman, R., Wang, Z., & Wei, S. J. (2014). Tracing value-added and double counting in gross exports. *American Economic Review*, 104(2), 459-94.

Kowalski, P., Gonzalez, J. L., Ragoussis, A., & Ugarte, C. (2015). Participation of developing countries in global value chains: Implications for trade and trade-related policies. *OECD*.

Lee, N. (2024). Global production networks meets evolutionary economic geography. *Regional Studies*, 1-3.

Loecker, J. D. (2013). Detecting learning by exporting. *American Economic Journal: Microeconomics*, *5*(3), 1-21.

Los, B., Timmer, M. P., & de Vries, G. J. (2015). How global are global value chains? A new approach to measure international fragmentation. *Journal of Regional Science*, 55(1): 66–92.

Maraut, S., Dernis, H., Webb, C., Spiezia, V., & Guellec, D. (2008). The OECD REGPAT database: a presentation. *OECD*.

Marrocu, E., Paci, R., & Usai, S. (2013). Proximity, networking and knowledge production in Europe: What lessons for innovation policy? *Technological Forecasting and Social Change*, 80(8), 1484-1498.

Martin, R., & Sunley, P. (2006). Path dependence and regional economic evolution. *Journal of Economic Geography*, 6(4), 395-437.

Mazzi, C. T., Ndubuisi, G., & Avenyo, E. (2024). Learning-by-exporting in South Africa: The influence of global value chain (GVC) participation and technological capability. *African Journal of Science, Technology, Innovation and Development*, 1-18.

McCann P., & Ortega-Argilés, R. (2015). Smart Specialisation, Regional Growth and Applications to EU Cohesion Policy, *Regional Studies*, 49 (8), 1291-1302.

Miguelez, E., & Moreno, R. (2013). Research networks and inventors' mobility as drivers of innovation: evidence from Europe. *Regional Studies*, 47(10), 1668-1685.

Miguelez, E., & Moreno, R. (2018). Relatedness, external linkages and regional innovation in Europe. *Regional Studies*, 52(5), 688-701.

Miguelez, E., & Morrison, A. (2022). Migrant inventors as agents of technological change. *The Journal of Technology Transfer*, 1-24.

Morrison, A. (2008). Gatekeepers of knowledge within industrial districts: who they are, how they interact. *Regional Studies*, 42(6), 817-835.

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.

Morrison, A., Rabellotti, R., & Zirulia, L. (2013). When do global pipelines enhance the diffusion of knowledge in clusters?. *Economic Geography*, *89*(1), 77-96.

Neffke, F., Henning, M., & Boschma, R. (2011). How do regions diversify over time? Industry relatedness and the development of new growth paths in regions. *Economic Geography*, 87(3), 237-265.

Paci, R., & Usai, S. (2009). Knowledge flows across European regions. *The Annals of Regional Science*, 43, 669-690.

Pietrobelli C., & Rabellotti R. (2007). *Upgrading to Compete: SMEs, Clusters and Value Chains in Latin America*. Cambridge Mass.: Harvard University Press.

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

Pinheiro, F. L., Balland, P. A., Boschma, R., & Hartmann, D. (2022). The dark side of the geography of innovation: relatedness, complexity and regional inequality in Europe. *Regional Studies*, 1-16.

Ponte, S., & Sturgeon, T. (2014). Explaining governance in global value chains: A modular theory-building effort. *Review of International Political Economy*, 21(1), 195-223.

Poon, J. P. (2024). Regional capability, evolutionary economic geography and global production networks. *Regional Studies*, 1-4.

Rigby, D. L. (2015). Technological relatedness and knowledge space: Entry and exit of US cities from patent classes. *Regional Studies*, 49(11), 1922-1937.

Rigby, D. L., & Essletzbichler, J. (1997). Evolution, process variety, and regional trajectories of technological change in US manufacturing. *Economic Geography*, 73(3), 269-284.

Rodríguez-Pose, A. (2013). Do institutions matter for regional development?. *Regional Studies*, *47*(7), 1034-1047.

Rodríguez-Pose, A. (2021). Costs, incentives, and institutions in bridging evolutionary economic geography and global production networks. *Regional Studies*, *55*(6), 1011-1014.

Rodríguez-Pose, A., & Crescenzi, R. (2008). Research and development, spillovers, innovation systems, and the genesis of regional growth in Europe. *Regional Studies*, 42(1), 51-67.

Rodríguez-Pose, A., & Di Cataldo, M. (2015). Quality of government and innovative performance in the regions of Europe. *Journal of Economic Geography*, *15*(4), 673-706.

Salomon, R. M., & Shaver, J. M. (2005). Learning by exporting: new insights from examining firm innovation. *Journal of Economics & Management Strategy*, *14*(2), 431-460.

Savona, M., & Bontadini, F. (2023). Revisiting the natural resource curse: backward linkages for export diversification and structural economic transformation. *Development and Change*, *54*(2), 378-421.

Sebestyén, T., Braun, E., & Elekes, Z. (2024). *Resolving the complexity puzzle: economic complexity and positions in global value chains jointly explain economic development*. Utrecht University, Human Geography and Planning.

Storper, M. (1993). Regional 'worlds' of production: Learning and innovation in the technology districts of France, Italy and the USA. *Regional Studies*, 27(5), 433–455.

Tajoli, L., & Felice, G. (2018). Global value chains participation and knowledge spillovers in developed and developing countries: An empirical investigation. *The European Journal of Development Research*, 30, 505-532.

Thissen, M., Lankhuizen, M., van Oort, F., Los, B., & Diodato, D. (2018). EUREGIO: The construction of a global IO DATABASE with regional detail for Europe for 2000–2010. *Tinbergen Institute Discussion Paper* TI 2018-084/VI.

Thwaites, A. T. (1978). Technological change, mobile plants and regional development. *Regional Studies*, 12(4), 445-461.

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., & de Vries, G. J. (2015). An illustrated user guide to the world input–output database: The case of global automotive production. *Review of International Economics*, 23(3): 575–605.

Trippl, M., Grillitsch, M., & Isaksen, A. (2018). Exogenous sources of regional industrial change: Attraction and absorption of non-local knowledge for new path development. *Progress in Human Geography*, 42(5), 687-705.

Uyarra, E., Marzocchi, C., & Sorvik, J. (2018). How outward looking is smart specialisation? Rationales, drivers and barriers. *European Planning Studies*, 26, 2344–2363.

Van Looy, B., Vereyen, C., & Schmoch, U. (2014). Patent Statistics: Concordance IPC V8–NACE Rev. 2. *Eurostat, European Commission*.

Yeung, H. W. C. (2021). Regional worlds: from related variety in regional diversification to strategic coupling in global production networks. *Regional Studies*, 55(6), 989-1010.

Yeung, H. W. C. (2024). From regional to global and back again? A future agenda for regional evolution and (de) globalised production networks in regional studies. *Regional Studies*, 1-12.

Appendix I.- List of the 243 European NUTS-2 regions included in the analysis

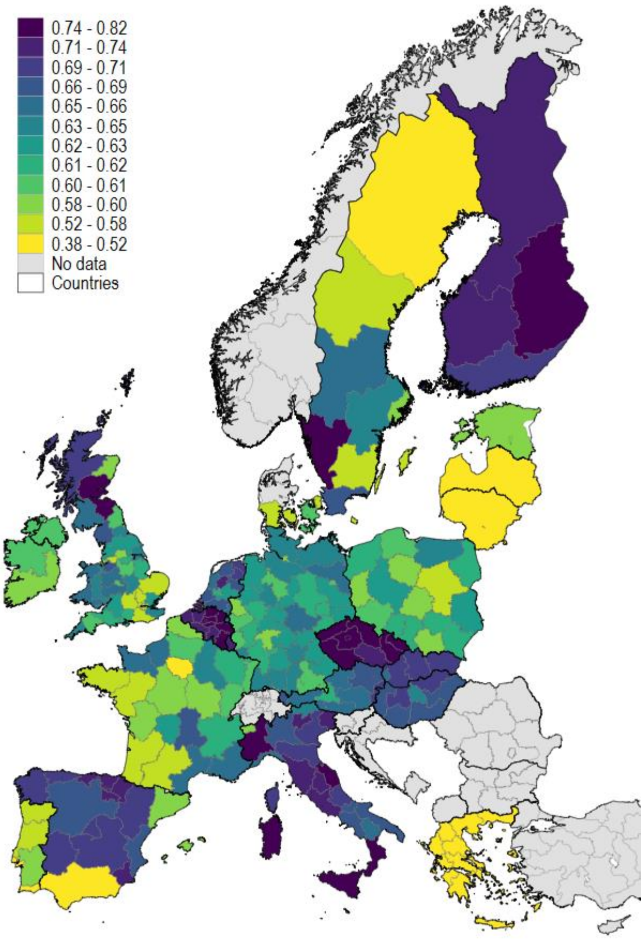
AT11	CZ06	DE94	ES23	FR42	GR43	ITH4	PL22	SE33	UKH3
AT12	CZ07	DEA1	ES24	FR43	HU10	ITH5	PL31	SI00	UKI1
AT13	CZ08	DEA2	ES30	FR51	HU21	ITI1	PL32	SK01	UKI2
AT21	DE11	DEA3	ES41	FR52	HU22	ITI2	PL33	SK02	UKJ1
AT22	DE12	DEA4	ES42	FR53	HU23	ITI3	PL34	SK03	UKJ2
AT31	DE13	DEA5	ES43	FR61	HU31	ITI4	PL41	SK04	UKJ3
AT32	DE14	DEB1	ES51	FR62	HU32	LT00	PL42	UKC1	UKJ4
AT33	DE21	DEB2	ES52	FR63	HU33	LU00	PL43	UKC2	UKK1
AT34	DE22	DEB3	ES53	FR71	IE01	LV00	PL51	UKD1	UKK2
BE10	DE23	DEC0	ES61	FR72	IE02	MT00	PL52	UKD3	UKK3
BE21	DE24	DED2	ES62	FR81	ITC1	NL11	PL61	UKD4	UKK4
BE22	DE25	DED4	ES70	FR82	ITC2	NL12	PL62	UKD6	UKL1
BE23	DE26	DED5	FI18	FR83	ITC3	NL13	PL63	UKD7	UKL2
BE24	DE27	DEE0	FI19	GR11	ITC4	NL21	PT11	UKE1	UKM2
BE25	DE30	DEF0	FI1D	GR12	ITF1	NL22	PT15	UKE2	UKM3
BE31	DE40	DEG0	FI20	GR13	ITF2	NL23	PT16	UKE3	UKM5
BE32	DE50	DK01	FR10	GR14	ITF3	NL31	PT17	UKE4	UKM6
BE33	DE60	DK02	FR21	GR21	ITF4	NL32	PT18	UKF1	UKN0
BE34	DE71	DK03	FR22	GR22	ITF5	NL33	SE11	UKF2	
BE35	DE72	EE00	FR23	GR23	ITF6	NL34	SE12	UKF3	
CZ01	DE73	ES11	FR24	GR24	ITG1	NL41	SE21	UKG1	
CZ02	DE80	ES12	FR25	GR25	ITG2	NL42	SE22	UKG2	
CZ03	DE91	ES13	FR26	GR30	ITH1	PL11	SE23	UKG3	
CZ04	DE92	ES21	FR30	GR41	ITH2	PL12	SE31	UKH1	
CZ05	DE93	ES22	FR41	GR42	ITH3	PL21	SE32	UKH2	

Appendix II.- Descriptive statistics

These two sub-measures (backward and forward global value chain participation) are two sides of the same coin, giving nonetheless some nuances referring to the way in which regions participate in global value chains. Regarding backward global value chain participation, the higher its value, the higher the foreign value added these regions receive and integrate in their own gross exports. In the case of forward global value chain participation, higher values indicate that these regions supply large amounts of domestic value added to third regions that are subsequently integrated in such regions' exports, in relation to their own gross exports.

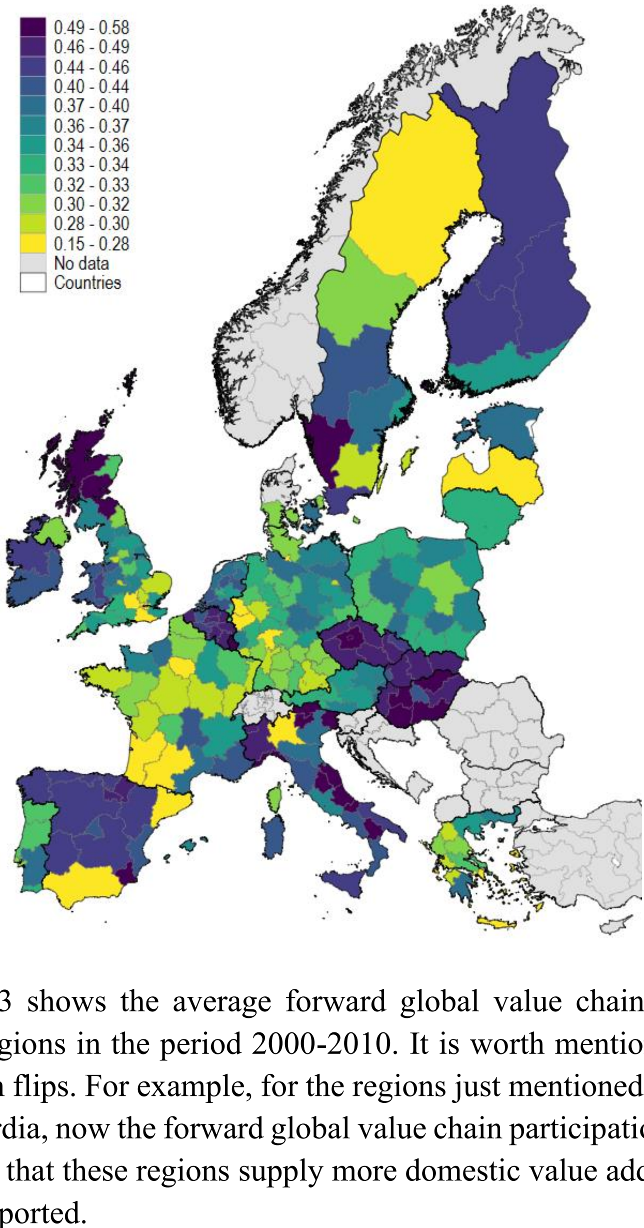
In this vein, Figure 1 presents the average total global value chain participation for the European NUTS-2 regions between the years 2000 and 2010. From this figure, it can be observed that European regions largely differ in their participation in global value chains. For example, regions from countries such as France and Germany do not exhibit high levels of engagement, while for regions in Spain, Italy, Belgium or the Czech Republic, the level of global value chain participation is notorious. This show how different regions are more (in-)dependent towards extra-regional supply and demand for intermediate inputs.

Figure 1.- Average total global value chain participation for European NUTS-2 regions between the years 2000-2010



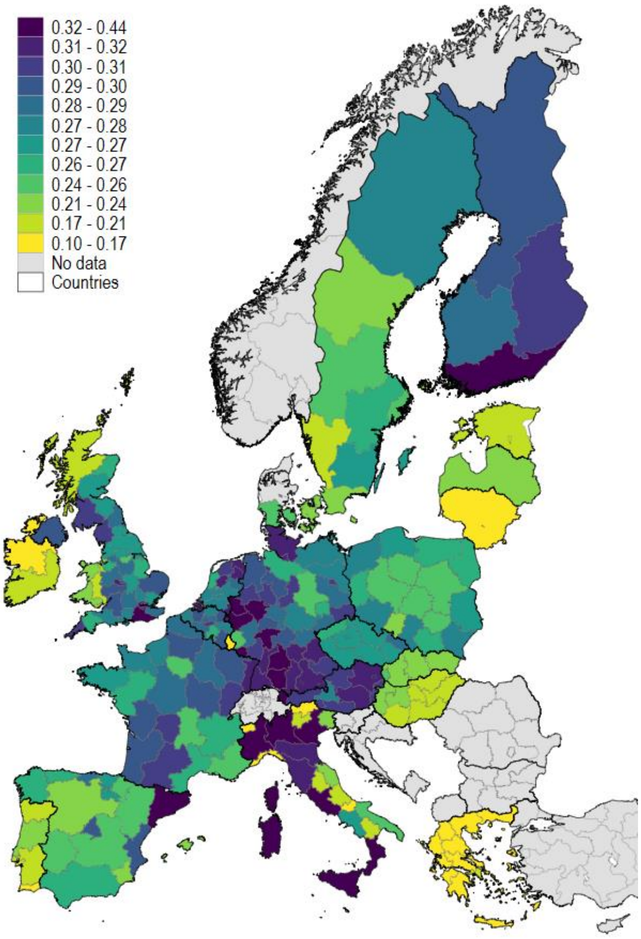
However, from Figure 1 while it is possible to assess the overall participation of regions in global value chains, it is not possible to assess the way in which they participate. Therefore, the total value chain participation is decomposed into backward and forward value chain participation to get more insights of what is driving this heterogeneity. Figure 2 shows the spatial distribution of backward global value chain participation. As it can be observed, it accounts for a similar picture than Figure 1. Nonetheless, it does show that some core regions such as Île-de-France, Cataluña and Lombardia, have low levels of backward participation.

Figure 2.- Average backward global value chain participation for European NUTS-2 regions between the years 2000-2010



Furthermore, Figure 3 shows the average forward global value chain participation for the European NUTS-2 regions in the period 2000-2010. It is worth mentioning that in this case, the spatial distribution flips. For example, for the regions just mentioned above, Île-de-France, Cataluña, and Lombardia, now the forward global value chain participation is notoriously high. In this case, it reflects that these regions supply more domestic value added to other regions to be subsequently re-exported.

Figure 3.- Average forward global value chain participation for European NUTS-2 regions between the years 2000-2010



Finally, the following table includes the summary statistics of the variables used in the empirical analysis. It is important to notice that all the variables are at the regional level but the entry and relatedness density, which are at the region - technology level. Also, notice that the number of observations for entry is lower than for the rest of variables because, as previously mentioned, when a region is already specialised in a certain technology, it cannot enter it the next time period.

Variables	**N**	**Mean**	**Std. Dev.**	**Min**	**Max**
Entry	381,431	0.1	0.3	0	1
Relatedness density	605,743	0.171	0.101	0	1
GVC total part.	605,743	0.637	0.079	0.374	0.838
GVC backward part.	605,743	0.372	0.077	0.139	0.605
GVC forward part.	605,743	0.265	0.057	0.076	0.467
GDP per capita	588,778	23,704.826	8,906.293	6,533.932	68,114.922
Population density	558,675	335.968	670.578	3.3	6,744.633
Patents	598,842	643.756	1,158.813	0.14	9,324.06
Human capital	572,466	23.076	8.589	5.6	50.45

Furthermore, the following tables include descriptive statistics by regional level of economic development.

A) Descriptive statistics for less developed regions

Variables	N	Mean	Std. Dev.	Min	Max
Entry	89,014	0.051	0.22	0	1
Relatedness density	144,502	0.069	0.066	0	1
GVC total part.	144,502	0.637	0.096	0.374	0.817
GVC backward part.	144,502	0.399	0.069	0.244	0.518
GVC forward part.	144,502	0.238	0.061	0.076	0.418
GDP per capita	144,502	13,233.271	3,278.044	6,533.932	17,721.543
Population density	125,692	136.697	180.742	22.05	1,304.167
Patents	144,502	60.74	111.424	0.14	755.28
Human capital	131,299	15.699	6.279	5.6	31.333

B) Descriptive statistics for transition regions

Variables	N	Mean	Std. Dev.	Min	Max
Entry	55,353	0.093	0.29	0	1
Relatedness density	92,411	0.164	0.096	0	1
GVC total part.	92,411	0.626	0.093	0.395	0.838
GVC backward part.	92,411	0.367	0.074	0.218	0.524
GVC forward part.	92,411	0.259	0.057	0.095	0.406
GDP per capita	92,411	19,759.341	1,007.149	17,816.857	21,308.201
Population density	91,781	119.544	114.661	3.3	1021.9
Patents	92,411	290.289	293.032	1	1,427.15
Human capital	91,781	22.551	6.35	8.908	35.625

C) Descriptive statistics for more developed regions

Variables	N	Mean	Std. Dev.	Min	Max
Entry	237,064	0.12	0.325	0	1
Relatedness density	368,830	0.212	0.084	0	1
GVC total part.	368,830	0.639	0.067	0.381	0.833
GVC backward part.	368,830	0.363	0.079	0.139	0.605
GVC forward part.	368,830	0.276	0.052	0.094	0.467
GDP per capita	351,865	29,041.437	7,102.892	21,336.203	68,114.922
Population density	341,202	467.592	822.291	3.3	6,744.633
Patents	361,929	966.778	1,386.73	0.5	9,324.06
Human capital	349,386	25.986	8.153	7.912	50.45

Appendix III.- Correlation matrices by regional level of economic development

A) Correlation matrix for all regions

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Entry	1.000								
(2) Relatedness density	0.258	1.000							
(3) GVC total part.	0.022	0.105	1.000						
(4) GVC backward part.	-0.045	-0.294	0.738	1.000					
(5) GVC forward part.	0.091	0.541	0.444	-0.276	1.000				
(6) GDP per capita	0.067	0.431	0.003	-0.130	0.178	1.000			
(7) Population density	0.027	0.149	-0.066	-0.167	0.128	0.404	1.000		
(8) Patents	0.068	0.532	-0.062	-0.308	0.321	0.380	0.111	1.000	
(9) Human capital	0.044	0.264	-0.031	-0.140	0.141	0.476	0.161	0.177	1.000

B) Correlation matrix for less developed regions

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Entry	1.000								
(2) Relatedness density	0.235	1.000							
(3) GVC total part.	0.043	0.225	1.000						
(4) GVC backward part.	0.010	0.038	0.805	1.000					
(5) GVC forward part.	0.059	0.328	0.748	0.209	1.000				
(6) GDP per capita	0.071	0.416	-0.053	-0.079	0.001	1.000			
(7) Population density	0.022	0.136	0.052	0.076	0.000	0.035	1.000		
(8) Patents	0.127	0.816	0.092	-0.059	0.217	0.324	0.071	1.000	
(9) Human capital	0.005	0.061	-0.352	-0.387	-0.148	0.255	-0.083	0.107	1.000

C) Correlation matrix for transition regions

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Entry	1.000								
(2) Relatedness density	0.277	1.000							
(3) GVC total part.	0.032	0.140	1.000						
(4) GVC backward part.	-0.037	-0.213	0.784	1.000					
(5) GVC forward part.	0.098	0.492	0.632	0.015	1.000				
(6) GDP per capita	0.041	0.223	0.039	-0.091	0.177	1.000			
(7) Population density	0.087	0.447	0.180	0.068	0.205	0.043	1.000		
(8) Patents	0.144	0.791	-0.001	-0.289	0.358	0.236	0.384	1.000	
(9) Human capital	0.069	0.357	0.122	-0.090	0.308	0.337	0.172	0.254	1.000

D) Correlation matrix for more developed regions

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Entry	1.000								
(2) Relatedness density	0.249	1.000							
(3) GVC total part.	0.014	0.101	1.000						
(4) GVC backward part.	-0.033	-0.281	0.753	1.000					
(5) GVC forward part.	0.068	0.552	0.211	-0.484	1.000				
(6) GDP per capita	-0.005	0.006	0.016	0.053	-0.059	1.000			
(7) Population density	0.007	0.030	-0.123	-0.175	0.096	0.378	1.000		
(8) Patents	0.040	0.495	-0.107	-0.314	0.324	0.216	0.035	1.000	
(9) Human capital	-0.015	-0.125	0.050	0.055	-0.015	0.201	0.089	0.018	1.000

Appendix IV.- Logit models for total, backward and forward global value chain participation

	Logit average marginal effects – Dependent variable: Entry (=1)					
	Total GVC Part.			Backward and Forward GVC Part.		
	(1) Baseline	(2) Full model	(3) Full model FEs	(4) Baseline	(5) Full model	(6) Full model FEs
Relatedness density (RD)	0.862***	0.947***	0.568***	0.862***	0.953***	0.569***
	(0.0978)	(0.0439)	(0.105)	(0.0976)	(0.0439)	(0.105)
GVC total part. (TGVC)	0.331**	0.0873***	0.406**			
	(0.154)	(0.0263)	(0.162)			
GVC backward part. (BGVC)				0.322*	0.0955***	0.397**
				(0.167)	(0.0263)	(0.174)
GVC forward part. (FGVC)				0.361	0.0492	0.432*
				(0.256)	(0.0493)	(0.253)
GDP per capita (log)		-0.00117	0.414***		-0.00175	0.414***
		(0.00712)	(0.0605)		(0.00700)	(0.0605)
Population density (log)		0.00379**	-0.103		0.00399**	-0.103
		(0.00168)	(0.134)		(0.00173)	(0.134)
Patents (log)		-0.0235***	0.0132		-0.0229***	0.0133
		(0.00277)	(0.0108)		(0.00280)	(0.0108)
Human capital (log)		0.0192***	0.0283		0.0189***	0.0283
		(0.00592)	(0.0252)		(0.00581)	(0.0252)
Observations	51,208	342,278	51,208	51,208	342,278	51,208
Region-Tech FEs	YES	NO	YES	YES	NO	YES
Period FEs	YES	NO	YES	YES	NO	YES

Notes. All independent variables are mean centred and lagged by one period. Heteroskedasticity-robust standard errors (clustered at the regional level) are shown in parentheses for models 2 and 5. Coefficients are statistically significant at the * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ level.

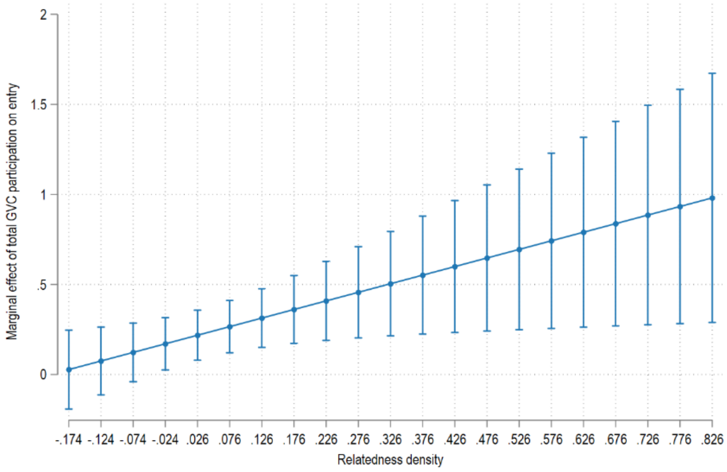
Appendix V.- Probit models for total, backward and forward global value chain participation

	Probit average marginal effects – Dependent variable: Entry (=1)			
	Total GVC part.		Backward - Forward GVC part.	
	(1)	(2)	(3)	(4)
	Baseline	Full model	Baseline	Full model
Relatedness density	0.614***	0.951***	0.652***	0.957***
	(0.0216)	(0.0445)	(0.0236)	(0.0443)
GVC total part.	0.0754***	0.0888***		
	(0.0215)	(0.0257)		
GVC backward part.			0.101***	0.0993***
			(0.0245)	(0.0260)
GVC forward part.			-0.0279	0.0481
			(0.0378)	(0.0449)
GDP per capita (log)		-0.00130		-0.00211
		(0.00661)		(0.00649)
Population density (log)		0.00329**		0.00348**
		(0.00162)		(0.00167)
Patents (log)		-0.0225***		-0.0219***
		(0.00278)		(0.00279)
Human capital (log)		0.0159***		0.0159***
		(0.00566)		(0.00554)
Observations	342,278	342,278	342,278	342,278
Region-Tech FEs	NO	NO	NO	NO
Period FEs	YES	YES	YES	YES

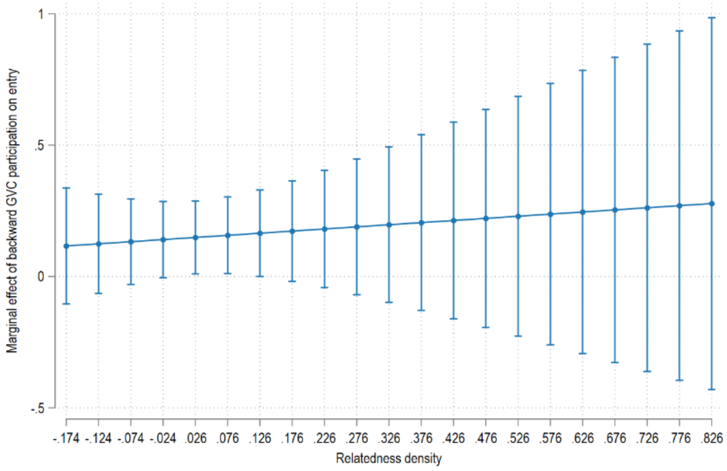
Notes. All independent variables are mean centred and lagged by one period. Heteroskedasticity-robust standard errors (clustered at the regional level) are shown in parentheses. Coefficients are statistically significant at the * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ level.

Appendix VI.- Plots for the marginal effects of GVC participation and relatedness density

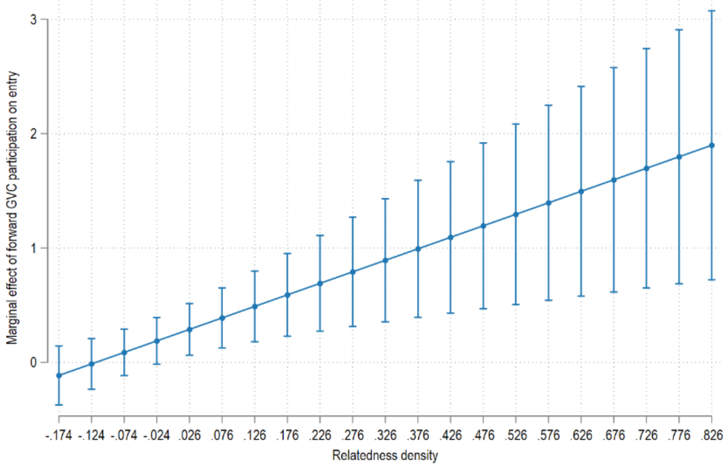
A) Total GVC participation and relatedness density



B) Backward GVC participation and relatedness density



C) Forward GVC participation and relatedness density

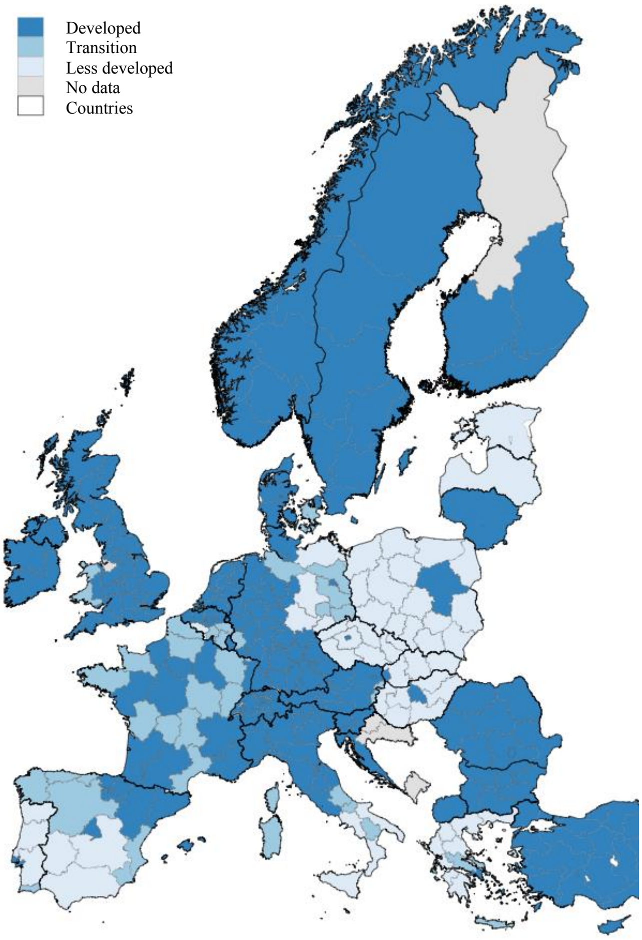


Appendix VII.- Entry models (LPM) for total, backward and forward participation in selected industries

	LPM – Dependent variable: Entry (=1)						
	Total GVC Participation			Backward and Forward GVC Participation			
	(1) Baseline	(2) Full model FEs	(3) Interaction	(4) Baseline	(5) Full model FEs	(6) Backward Interaction	(7) Forward Interaction
Relatedness density (RD)	0.254***	0.311***	0.312***	0.257***	0.313***	0.320***	0.295***
	(0.0448)	(0.0465)	(0.0457)	(0.0447)	(0.0464)	(0.0458)	(0.0473)
GVC total part. (TGVC)	0.173**	0.160**	0.173***				
	(0.0676)	(0.0691)	(0.0650)				
RD * TGVC			1.174***				
			(0.339)				
GVC backward (BGVC)				0.187***	0.169***	0.174***	0.173***
				(0.0631)	(0.0647)	(0.0634)	(0.0630)
GVC forward (FGVC)				0.0805	0.0998	0.0759	0.205
				(0.147)	(0.144)	(0.144)	(0.144)
RD * BGVC						0.619*	
						(0.350)	
RD * FGVC							1.845**
							(0.736)
GDP per capita (log)		-0.0174	-0.0129		-0.0174	-0.0162	-0.0139
		(0.0236)	(0.0222)		(0.0233)	(0.0229)	(0.0227)
Population density (log)		-0.0374	-0.0415		-0.0343	-0.0356	-0.0376
		(0.0546)	(0.0533)		(0.0550)	(0.0553)	(0.0527)
Patents (log)		-0.00967**	-0.00920**		-0.00956**	-0.00988**	-0.00790**
		(0.00381)	(0.00382)		(0.00384)	(0.00383)	(0.00396)
Human capital (log)		-0.0174	-0.0119		-0.0172	-0.0156	-0.0136
		(0.0121)	(0.0117)		(0.0121)	(0.0119)	(0.0121)
Constant	0.0731***	0.0606***	0.0638***	0.0731***	0.0609***	0.0635***	0.0581***
	(0.00195)	(0.00553)	(0.00550)	(0.00196)	(0.00556)	(0.00569)	(0.00543)
Observations	342,278	342,278	342,278	342,278	342,278	342,278	342,278
Adjusted R^2	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Region-Tech FEs	YES	YES	YES	YES	YES	YES	YES
Period FEs	YES	YES	YES	YES	YES	YES	YES

Notes. All independent variables are mean centred and lagged by one period. Heteroskedasticity-robust standard errors (clustered at the regional level) are shown in parentheses. Coefficients are statistically significant at the * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ level.

Appendix VIII.- Less developed, transition, and developed regions by their average GDP per capita between 2000-2010.



Appendix IX.- Entry models (LPM) for total, backward and forward participation in less developed regions

	LPM – Dependent variable: Entry (=1)						
	GVC Total Participation			GVC Backward and Forward Participation			
	(1) Baseline	(2) Full model FEs	(3) Total Interaction	(4) Baseline	(5) Full model FEs	(6) Backward Interaction	(7) Forward Interaction
Relatedness density (RD)	0.758***	0.851***	0.843***	0.763***	0.861***	0.892***	0.942***
	(0.138)	(0.141)	(0.137)	(0.136)	(0.143)	(0.147)	(0.140)
GVC total part. (TGVC)	0.0863	0.157	0.179*				
	(0.143)	(0.0984)	(0.100)				
RD * TGVC			0.331				
			(0.668)				
GVC backward part. (BGVC)				0.0682	0.124	0.0562	-0.0332
				(0.152)	(0.115)	(0.138)	(0.118)
GVC forward part. (FGVC)				0.119	0.214	0.243	0.790***
				(0.198)	(0.144)	(0.162)	(0.261)
RD * BGVC						-0.811	
						(1.076)	
RD * FGVC							3.936**
							(1.690)
GDP per capita (log)		0.107**	0.108**		0.107**	0.105**	0.118***
		(0.0418)	(0.0422)		(0.0411)	(0.0427)	(0.0409)
Population density (log)		0.266	0.264		0.262	0.270	0.261
		(0.259)	(0.260)		(0.257)	(0.257)	(0.257)
Patents (log)		-0.0122***	-0.0117***		-0.0127***	-0.0133***	-0.0104***
		(0.00320)	(0.00345)		(0.00328)	(0.00329)	(0.00356)
Human capital (log)		0.0299	0.0314		0.0286	0.0273	0.0366
		(0.0236)	(0.0246)		(0.0238)	(0.0236)	(0.0249)
Constant	0.129***	0.328**	0.329**	0.132***	0.328**	0.332**	0.362**
	(0.0183)	(0.140)	(0.142)	(0.0187)	(0.138)	(0.137)	(0.140)
Observations	74,335	74,335	74,335	74,335	74,335	74,335	74,335
Adjusted R^2	0.023	0.024	0.024	0.023	0.024	0.024	0.024
Region-Tech FEs	YES	YES	YES	YES	YES	YES	YES
Period FEs	YES	YES	YES	YES	YES	YES	YES

Notes. All independent variables are mean centred and lagged by one period. Heteroskedasticity-robust standard errors (clustered at the regional level) are shown in parentheses. Coefficients are statistically significant at the * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ level.

Appendix X.- Entry models (LPM) for total, backward and forward participation in transition regions

	LPM – Dependent variable: Entry (=1)						
	GVC Total Participation			GVC Backward and Forward Participation			
	(1) Baseline	(2) Full model FEs	(3) Total Interaction	(4) Baseline	(5) Full model FEs	(6) Backward Interaction	(7) Forward Interaction
Relatedness density (RD)	0.250	0.599**	0.756***	0.475	0.600**	0.885***	0.581**
	(0.427)	(0.276)	(0.269)	(0.331)	(0.275)	(0.305)	(0.272)
GVC total part. (TGVC)	1.116	1.678***	1.813***				
	(0.712)	(0.572)	(0.613)				
RD * TGVC			4.409**				
			(2.168)				
GVC backward part. (BGVC)				1.969**	1.693**	1.917**	1.667**
				(0.924)	(0.781)	(0.853)	(0.790)
GVC forward part. (FGVC)				0.125	1.641	1.238	1.823
				(0.601)	(1.003)	(1.010)	(1.646)
RD * BGVC						5.902**	
						(2.391)	
RD * FGVC							1.445
							(7.109)
GDP per capita (log)		-0.551	-0.476		-0.555	-0.744	-0.480
		(1.041)	(1.045)		(1.014)	(0.990)	(1.199)
Population density (log)		2.302***	2.199***		2.284***	2.257***	2.275***
		(0.354)	(0.328)		(0.577)	(0.515)	(0.567)
Patents (log)		-0.0404	-0.0311		-0.0396	-0.0242	-0.0412
		(0.0625)	(0.0607)		(0.0591)	(0.0581)	(0.0633)
Human capital (log)		0.0222	0.0493		0.0223	0.0206	0.0315
		(0.159)	(0.162)		(0.160)	(0.163)	(0.177)
Constant	0.0830***	1.452***	1.414***	0.0826***	1.440***	1.405***	1.449***
	(0.0255)	(0.278)	(0.270)	(0.0233)	(0.369)	(0.333)	(0.391)
Observations	33,949	33,949	33,949	33,949	33,949	33,949	33,949
Adjusted R^2	0.027	0.034	0.034	0.029	0.034	0.034	0.034
Region-Tech FEs	YES	YES	YES	YES	YES	YES	YES
Period FEs	YES	YES	YES	YES	YES	YES	YES

Notes. All independent variables are mean centred and lagged by one period. Heteroskedasticity-robust standard errors (clustered at the regional level) are shown in parentheses. Coefficients are statistically significant at the * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ level.

Appendix XI.- Entry models (LPM) for total, backward and forward participation in more developed regions

	LPM – Dependent variable: Entry (=1)						
	GVC Total Participation			GVC Backward and Forward Participation			
	(1) Baseline	(2) Full model FEs	(3) Total Interaction	(4) Baseline	(5) Full model FEs	(6) Backward Interaction	(7) Forward Interaction
Relatedness density (RD)	0.190***	0.175***	0.189***	0.192***	0.177***	0.198***	0.133**
	(0.0582)	(0.0584)	(0.0604)	(0.0590)	(0.0586)	(0.0616)	(0.0641)
GVC total part. (TGVC)	0.243**	0.191	0.0643				
	(0.122)	(0.115)	(0.111)				
RD * TGVC			2.420***				
			(0.855)				
GVC backward part. (BGVC)				0.219*	0.177	0.124	0.181*
				(0.117)	(0.111)	(0.120)	(0.103)
GVC forward part. (FGVC)				0.377*	0.296	0.295	0.112
				(0.222)	(0.231)	(0.238)	(0.233)
RD * BGVC						1.013	
						(0.748)	
RD * FGVC							2.852***
							(1.085)
GDP per capita (log)		-0.00498	0.0188		-0.00709	-0.00211	0.00760
		(0.0520)	(0.0494)		(0.0526)	(0.0534)	(0.0474)
Population density (log)		-0.177**	-0.154*		-0.169*	-0.155*	-0.184**
		(0.0862)	(0.0832)		(0.0876)	(0.0863)	(0.0811)
Patents (log)		0.00741	0.00150		0.00775	0.00426	0.0105
		(0.00999)	(0.00821)		(0.0101)	(0.00910)	(0.00948)
Human capital (log)		-0.00758	-0.00462		-0.00685	-0.00645	-0.00475
		(0.0195)	(0.0194)		(0.0196)	(0.0197)	(0.0197)
Constant	0.0731***	0.130***	0.122***	0.0715***	0.127***	0.124***	0.124***
	(0.00180)	(0.0297)	(0.0290)	(0.00253)	(0.0306)	(0.0307)	(0.0282)
Observations	187,629	187,629	187,629	187,629	187,629	187,629	187,629
Adjusted R^2	0.019	0.019	0.019	0.019	0.019	0.019	0.019
Region-Tech FEs	YES	YES	YES	YES	YES	YES	YES
Period FEs	YES	YES	YES	YES	YES	YES	YES

Notes. All independent variables are mean centred and lagged by one period. Heteroskedasticity-robust standard errors (clustered at the regional level) are shown in parentheses. Coefficients are statistically significant at the * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ level.