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The importance of trade and technology for productivity: An empirical assessment across EU regions☆

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ABSTRACT

This paper investigates the relationship between trade, technology, and regional productivity growth across European Union regions between 2017 and 2023. Leveraging newly available NUTS-2 level data on interregional and international trade flows, we estimate a series of Barro-type growth regressions derived from the Solow model and extended to include institutional quality, foreign direct investment, urbanisation, and the COVID-19 shock. The analysis confirms conditional convergence: less productive regions tend to grow faster, particularly when supported by higher capital intensity and employment in high-tech sectors.

Trade exposure is positively associated with productivity growth, but this relationship is not uniform. Regions more engaged in extra-EU trade — particularly those exporting final goods beyond the EU or importing capital goods from abroad — experience stronger productivity gains. In contrast, a higher share of final goods exports within the EU is linked to weaker performance, suggesting possible saturation or weaker technological spillovers within the Single Market.

These findings underscore the importance of trade composition and direction in shaping regional development. They highlight the need for EU policies that enhance technological capacity and facilitate global market access for lagging regions. Supporting targeted integration into global value chains, especially in capital-intensive sectors, may offer a pathway to more equitable productivity growth across the Union.

1. Introduction

The uneven distribution of productivity growth across European regions has emerged as a central concern for both economists and policymakers. While trade and technological progress are widely recognised as engines of economic development, their effects are neither spatially neutral nor uniformly distributed. Classical trade theory long assumed national homogeneity, but empirical research increasingly demonstrates that regional characteristics — such as industrial structure, innovation capacity, and proximity to global markets — significantly mediate the impact of trade and technology on productivity. This pattern is consistent with insights from the New Economic Geography, which emphasises how agglomeration forces and increasing returns can amplify the spatial concentration of economic activity. According to this framework, trade openness and market integration may raise overall productivity while simultaneously deepening regional disparities. From a methodological standpoint, the regional dimension remains understudied, largely due to historical limitations in subnational trade data. This is all but ideal, since disparities within the EU are notably more persistent at the regional level, despite various policy initiatives aimed at fostering convergence, such as EU structural

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funds and cohesion policies. For instance, while intra-EU trade accounts for over 60% of Slovakia's exports, its benefits concentrate in Bratislava's automotive cluster, leaving eastern regions like Prešov behind (OECD, 2021). Similarly, EU cohesion policies, which allocated €391 billion to reduce regional disparities between 2014 and 2020, often prioritise infrastructure over capabilities, funding highways in Bulgaria's rural areas but failing to equip local firms with the skills or technology to compete in global value chains. This mismatch underscores a pressing need to rethink how trade and technology policies interact with subnational economic geography. The European Commission (2022) has documented the continued economic divergence between peripheral and core regions within the EU. While some regions, particularly in Central and Eastern Europe, have seen convergence in terms of productivity and income levels since their accession to the EU, many other regions, particularly in Southern and Eastern Europe, have lagged behind. These imbalances are not only a result of different levels of initial development but also reflect deep structural differences in terms of industry specialisation, technological adoption, and integration into global markets. For example, while some Central and Eastern European regions have successfully integrated into supply chains, other regions have struggled with low-tech industries or even declining sectors. These ongoing disparities underscore the necessity of investigating the underlying drivers of regional productivity growth in more detail, including the roles that trade and technology play in shaping the development trajectories of different regions.

This paper contributes to the literature by empirically examining how trade, technology, and structural and institutional factors shape productivity growth at the regional level across the European Union. Using newly available NUTS-2 level data from the Joint Research Centre that map both intra- and international trade flows, we estimate a series of Barro-type growth regressions derived from the Solow model. Beyond assessing the effects of trade intensity and technological specialisation, we extend the analysis to include institutional quality, foreign direct investment, urbanisation, and the COVID-19 pandemic shock. We analyse three underexplored dimensions: (1) the different impacts of intra-EU versus extra-EU trade, (2) the role of trade composition, and (3) the mediating effect of regional technological specialisation. This approach allows us to explore whether and how trade intensity, trade composition, and technological specialisation were associated with productivity convergence (or divergence) among EU regions between 2017 and 2023.

We find robust evidence of conditional convergence: less productive regions tend to grow faster, particularly when supported by strong capital stock and high-tech employment. More importantly, trade exposure is positively associated with productivity growth—but not uniformly so. Extra-EU trade appears more strongly correlated with regional upgrading than intra-EU trade, and capital goods imports play a significant role in enhancing productivity. These findings suggest that the benefits of globalisation and technological diffusion are conditional, mediated by the type and direction of trade, and contingent upon regional absorptive capacities. Moreover, institutional quality, foreign direct investment, and structural characteristics such as urbanisation further shape these dynamics, reinforcing the view that productivity growth in Europe is driven by a complex interplay between openness, technological capability, and governance. The robustness of these patterns across different productivity measures highlights their consistency and policy relevance. Our results carry important implications for EU cohesion policy and the broader debate on inclusive growth in a globalised economy.

2. Literature review

The question of what drives regional productivity growth has been a central concern for economists and policymakers, especially in the context of regional disparities within the European Union. Although substantial academic attention has been devoted to understanding national growth dynamics, subnational regions present a more complex and varied landscape where productivity dynamics may differ significantly due to local factors such as trade openness, sectoral composition, technology, and institutional settings. These regional differences, especially in the EU, have profound implications for policy aimed at enhancing growth and reducing disparities across member states.

A key theoretical foundation for examining regional productivity growth is the neoclassical growth model, particularly the Solow-Swan model, which posits that regions with lower initial levels of productivity should exhibit faster growth rates, conditional on certain factors such as human capital, infrastructure, and investment. Empirical work on regional convergence, especially in the European context, has provided mixed results. While studies by Barro and Sala-i Martin (1991) and Barro (2004) have supported the idea of conditional convergence — whereby poorer regions grow faster, narrowing the productivity gap with richer ones — this process is often slow and uneven. Several factors can influence this convergence, including the level of capital investment, the availability of skilled labour, and the extent of technological adoption.

The role of trade openness in regional productivity growth has been a growing area of interest in recent years. Classical trade theory, as first outlined by David Ricardo and later developed by Heckscher and Ohlin, emphasises the efficiency gains that arise from countries (or regions) specialising in industries where they have a comparative advantage. This specialisation leads to more efficient allocation of resources and higher productivity. In the context of regional productivity, however, the benefits of trade openness may vary. The extent to which trade leads to productivity growth in a given region depends on several factors, such as the level of technology in the traded goods, market access, and the region's degree of integration into global supply chains. In particular, the New Economic Geography (NEG) challenges the notion of distributive neutrality in trade due to the presence of agglomeration effects driven by local increasing returns. Krugman (1991) theorises that producers tend to cluster in areas with substantial demand to reduce transport costs and exploit economies of scale. This behaviour leads to the formation of economic clusters — often in cities or regions with favourable initial conditions — while peripheral areas tend to be left behind. These clusters, typically centred around tradable goods and services, boost total factor productivity and industry-specific growth, yet can cause specific industries and regions to stagnate. However, the conclusions drawn from NEG models remain conflicting. Depending on assumptions regarding dispersion forces, international trade can either augment (Paluzie, 2001) or reduce (Krugman and Elizondo, 1996) regional income disparities. All in all, according to NEG, deeper European integration has raised overall productivity and trade but also tended to concentrate benefits in core, better-connected regions through agglomeration forces. These differences in trade dynamics are further compounded by the geographical and economic concentration of high-value industries in certain EU regions. For example, regions that are more integrated with global markets or those specialising in high-tech industries often experience greater productivity growth from increased trade, due to access to more advanced goods, technologies, and knowledge. In contrast, trade within the EU, characterised by greater market integration and often lower product differentiation, may yield diminishing returns, particularly in more mature industries (Brun et al., 2005).

The composition of trade — particularly the types of goods traded — also plays a critical role in determining regional productivity outcomes. Coe and Helpman (1995) and Keller (2004) argue that imports of capital goods and advanced technologies can lead to productivity gains by facilitating technological upgrading and enhancing production processes. In this sense, trade is not simply about the volume of goods exchanged but also about the technological content of those goods. Regions with greater imports of capital goods, especially from outside the EU, may experience stronger productivity growth due to the technological spillovers embedded in these goods. Such imports may allow regions to access cutting-edge technologies, machinery, and expertise that would otherwise be unavailable locally. This argument is consistent with findings from studies by Mo et al. (2021), who demonstrate that technology-intensive imports, especially in manufacturing sectors, are a key driver of productivity improvements at the regional level. Similarly, exports, especially to extra-EU markets, can catalyse productivity growth by exposing firms to global competition, increasing the demand for high-value products, and stimulating innovation. As noted by Békés and Murakozy (2012), firms that export are often more productive due to the pressures and learning associated with competing in international markets. Moreover, exporting to markets outside the EU can open up opportunities for firms to specialise in high-technology sectors, where product differentiation and innovation are more likely to drive productivity increases. The positive association between exports and productivity growth, particularly in regions that are exporters of high-tech goods, has been confirmed by several empirical studies (e.g., Castellani et al., 2010). In contrast, exports to EU markets, where product differentiation may be lower, appear to have a more muted effect on productivity.

In addition to trade, technological specialisation and innovation capacity are crucial drivers of regional productivity growth. Endogenous growth models, such as those proposed by Romer (1990) and Aghion and Howitt (1998), emphasise the role of innovation in driving sustained economic growth. At the regional level, this argument holds particular relevance. The presence of high-tech industries, characterised by greater research and development (R&D) intensity, higher capital intensity, and a highly skilled workforce, has been shown to be strongly correlated with higher rates of productivity growth. Rodríguez-Pose (2013) argues that the regional innovation environment, including local institutions, universities, and research centres, plays a crucial role in fostering technological advancements that enhance productivity. Several studies have shown that regions with a higher share of employment in high-tech industries or those investing heavily in R&D tend to experience faster productivity growth. For example, Hilson (2008) demonstrates that innovation hubs, such as those in Northern Europe, exhibit superior productivity performance due to the concentration of high-tech sectors and the robustness of local innovation ecosystems. This idea is echoed by the JRC (Bauer et al., 2020), which highlights the importance of a strong institutional framework and access to knowledge in driving regional economic growth. In these regions, firms benefit from substantial synergies between academia, government, and private industry, which foster an environment conducive to technological advancement and, consequently, higher productivity.

The interaction between trade and technology adds another layer of complexity to the analysis of regional productivity. As Crescenzi et al. (2007) point out, trade openness does not automatically lead to higher productivity in all regions; rather, it depends on a region's ability to absorb and capitalise on the knowledge and technologies embedded in trade. Regions with high absorptive capacity, including a skilled workforce, strong R&D infrastructure, and advanced industrial capabilities, are better positioned to translate trade into productivity growth. Conversely, regions with lower levels of technological capacity or weaker innovation systems may struggle to benefit from trade, especially if they are primarily engaged in the exchange of low-value-added goods.

The literature suggests that while trade and technology are crucial drivers of productivity growth, their effects are not homogeneous across regions. Factors such as sectoral composition, institutional quality, and the extent of regional integration into global markets all play a role in shaping the outcomes of trade and technological investment. The relationship between trade, technology, and productivity growth is thus contingent upon a variety of regional characteristics, and the benefits of trade openness and technological innovation are likely to be more pronounced in regions that are better equipped to leverage these opportunities. In summary, it appears that regional productivity growth is influenced by a complex array of factors, with trade and technology being two of the most significant drivers. However, the effects of these factors are not uniform across regions. The ability to capitalise on the benefits of trade and technology depends on a region's initial conditions, institutional settings, and industrial structure. Understanding these dynamics is crucial for designing policies that foster more inclusive and sustainable growth across the EU's diverse regions. As EU regions continue to face challenges such as demographic shifts, globalisation, and technological disruption, further research is needed to explore how regional policy frameworks can better support areas that struggle to realise the full potential of trade and technological advancements.

3. Data and regional patterns

The European Union (EU) stands as one of the most economically integrated regions in the world, featuring internal free trade, a robust industrial base, and for many of its member states, a shared monetary policy. However, analysing the EU's economic performance and dynamics at the macroeconomic level often masks the considerable heterogeneity that exists at the regional scale.

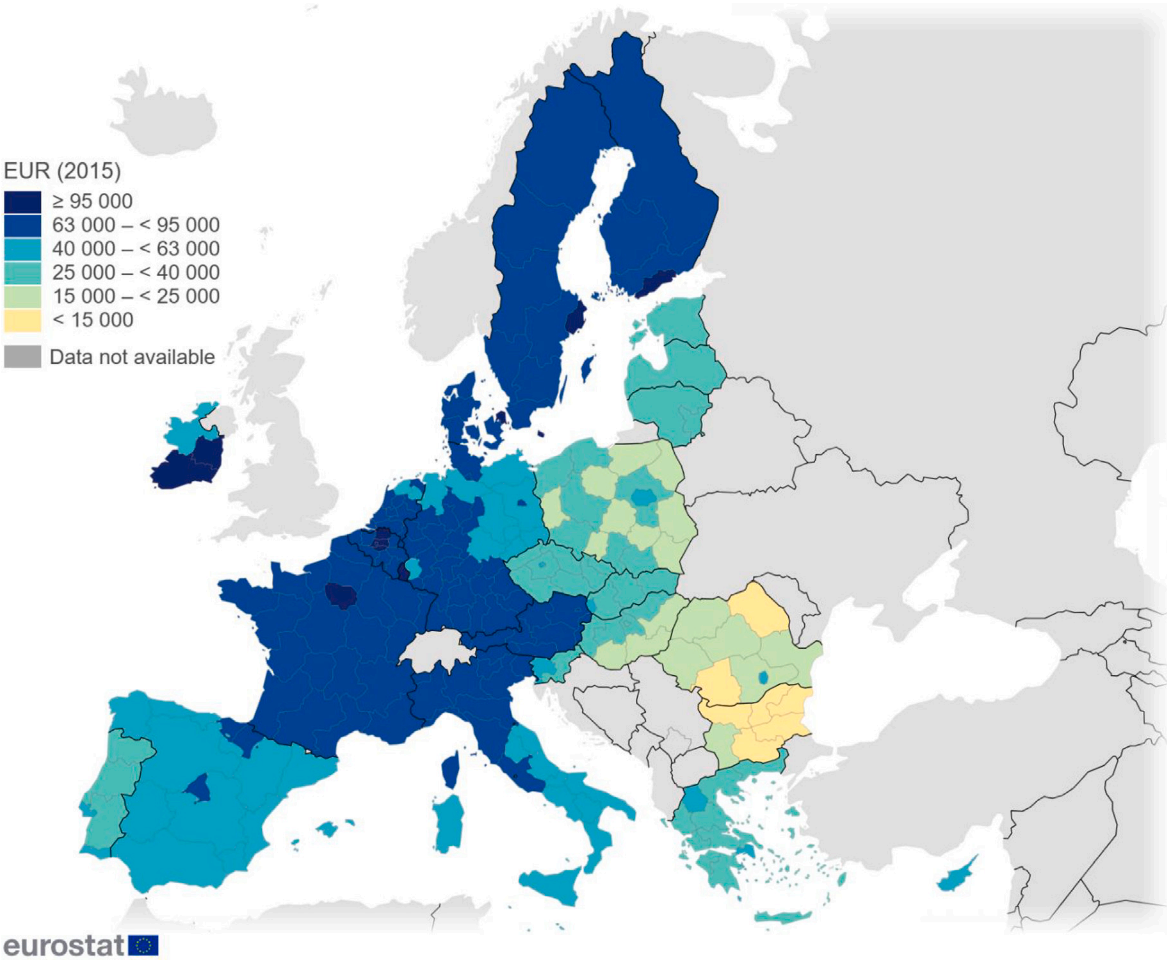

Fig. 1. Employee productivity in 2017.
Source: Authors' elaboration on ARDECO data.

This becomes particularly evident when one examines the substantial productivity disparities that persist not just across countries but within countries as well. As illustrated in Fig. 1, these disparities are not limited to inter-country differences but are also pronounced within broader macro-areas. This is a crucial aspect to consider, as it challenges the notion of a uniform economic development trajectory across the European Union, and suggests that internal dynamics within individual regions might offer important insights into the larger picture of EU economic performance.

A closer examination of regional productivity across the EU reveals a tiered structure of economic development. At the highest end of this spectrum, regions such as Paris, Luxembourg, the Flanders, Southern Ireland, and the capital cities of the Nordic countries form the first tier, characterised by extremely high productivity levels. These areas benefit from a combination of factors, including highly skilled labour, technological innovation, and capital accumulation. A second tier encompasses regions that represent the economic core of Europe, including parts of France, Belgium, the Netherlands, Western Germany, Austria, Northern Italy, and the Nordic countries. This zone also includes key economic centres such as Madrid, Rome, Berlin, and the Basque Country, all of which exhibit strong economic performance, albeit to a slightly lesser degree than the first tier.

The third tier includes much of Western Europe, excluding parts of Portugal, as well as regions like Warsaw, Bucharest, Athens, Prague, Bratislava, and Ljubljana. The regions in this tier show relatively moderate productivity levels, reflecting a mixture of more advanced areas alongside those with emerging industries and labour force development. The fourth tier consists of the most economically underdeveloped parts of Portugal, Greece, the Baltic countries, and parts of Eastern Europe, including Czechia, Slovakia, and the more productive areas of Poland and Hungary. Finally, the fifth and sixth tiers are made up of the less developed regions in Eastern Europe, where productivity levels remain significantly lower, driven by a combination of historical, institutional, and structural factors.

While the general trend shows that productivity declines as one moves away from the economic centre of Europe — a phenomenon that has been discussed in the literature as the "European development centre" (Petrakos and Economou, 2003) — there are notable exceptions. Capital cities, for instance, often outperform surrounding regions, and in some cases, these areas are able to attract substantial investments, industries, and talent that further drive economic growth. However, this productivity advantage does not always seem to spill over significantly to neighbouring regions. This finding is consistent with the work of Traistaru et al. (2002), who argue that the distance from other EU regions plays a more significant role in shaping regional growth patterns than proximity to the national capital. The Irish case, where foreign direct investment (FDI) and tax policy have had a substantial impact on regional economic performance (Barry and Bradley, 1997), and the Scandinavian countries, with their cohesive innovation systems and robust institutions (Hilson, 2008), represent other notable exceptions to the broader trend.

Despite the growing importance of regions in explaining European economic performance, comprehensive analyses of how trade affects productivity at the regional level remain rare. Existing studies tend to focus on individual countries.[1] Their trade data is limited either in scope (e.g., only manufacturing and no services) or reliability (only truck-shipped goods are considered, and general proxies are used to infer the degree of trade openness). Concerning the association between trade and economic growth, Resmini (2020, p. 399) notes that «empirical evidence on the relationship […] at regional level is rather rare because of the lack of consistent data on regional international trade flows». Recently, however, the EU Commission's Joint Research Centre has estimated regional trade flows in 2017 at the NUTS-2 level, assembling multi-regional Input-Output tables. Garcia-Rodriguez et al. (2023) provide a detailed description of the construction process and of its use for the RHOMOLO V4 model.

The dataset shows interregional flows originating from and directed to each NUTS-2 region in the European Union, allowing the identification of both intra-national trade (i.e., trade between regions that belong to the same country) and international trade (i.e., trade between regions belonging to different countries). The availability of domestic trade data is certainly not to be underestimated. In a study on the relationship between trade and economic growth in Spanish regions, Laurin (2012) lamented their unavailability. Similarly, Breinlich (2006, p. 599) acknowledged that «there are virtually no data on trade flows at regional level for the European Union» and had to rely on «the assumption […] that interregional flows are governed by similar underlying forces as international ones».

Fig. 2 shows the incidence of out-of-region (i.e., both domestic and international) trade on GDP for NUTS-2 regions. Unsurprisingly, the most crucial determinant of a region's propensity to trade seems to be its geographic centrality: a nucleus of highly trade-intensive regions stretches from Belgium through Germany and Czechia to Poland, Slovakia and Hungary. Such a pattern seems to be somehow fractal since also, within individual countries, centrally-located regions seem to trade more than peripheral ones: this reflects the well-known *home-bias* in trade,[2] recently investigated in a similar framework by Santamaría et al. (2023). Capital cities and economic powerhouses (such as Lombardy and Catalonia) appear less trade-intensive in relative terms because their high GDP inflates the denominator, though in absolute terms both intra- and inter-regional trade volumes remain significant.

The dataset allows us to distinguish trade with domestic regions from those in foreign countries. Such distinction seems crucial since about 60% of out-of-region trade in Europe originates from, or is directed to, other regions that belong to the same country. This propensity to trade with domestic regions is consistent with findings by Santamaría et al. (2023), who highlight a substantial "*home and country bias*" and estimate that only 19% of regional trade involves a foreign region. Our dataset confirms that, on average, European regions trade mainly within regional and national borders, with an average of only 30% of out-of-region flows originating from or destined to regions in other European or non-European countries.

Therefore, the availability of reliable trade data allows us to assess how changes in productivity might be associated with different levels of trade and technology. Fig. 3 shows that patterns of growth in productivity are quite complex. The substantial concentration of high-growth regions in the eastern part of the Continent represents the most evident pattern shown on the map. This is most likely due to the relatively lower initial productivity of regions in the East: they are attaining higher economic standards, either as a general phenomenon of convergence (as in Bhalla, 2002), or as a consequence of integration in an economic union with relatively wealthier regions (consistently with Venables, 2003). The relatively high growth rates in Southern European regions such as Portugal also support the convergence hypothesis, as these areas, despite not having joined the EU as recently as Eastern European countries, have still benefited from the overall economic integration of the Union.

In conclusion, the regional patterns of trade, productivity, and technology within the EU reveal a complex and multi-layered economic landscape. While proximity to the economic core of Europe tends to be associated with higher productivity and greater trade intensity, there are notable exceptions driven by factors such as FDI, innovation systems, and institutional quality. The availability of regional trade and employment data has allowed for a more nuanced analysis of how these factors intersect to shape regional economic outcomes. Understanding these regional dynamics is essential for crafting policies that promote balanced growth across the EU, particularly in the context of a rapidly evolving global economy.

4. Methodology

Our empirical approach builds on a standard adaptation of the Solow growth model (Solow, 1956), operationalised through a Barro-type growth regression (Barro, 1996), which has become a widely accepted framework for studying the determinants of regional and national economic performance. This specification allows us to test for convergence effects and to evaluate the role of capital, technology, and trade in driving regional productivity growth across the European Union between 2017 and 2023.

[1] Notably, Sun et al. (1999) for China; Leong (2013) for China and India; Buch and Toubal (2007) for Germany.

[2] A strand of research initiated when McCallum (1995) assessed that trade flows between Canadian provinces were about 22 times higher than trade with US states, when controlling for distance and other explanatory factors. Nitsch (2000, p 1091) estimates that «averaged over all EU countries, intranational trade is about ten times as high as international trade with an EU partner country of similar size and distance».

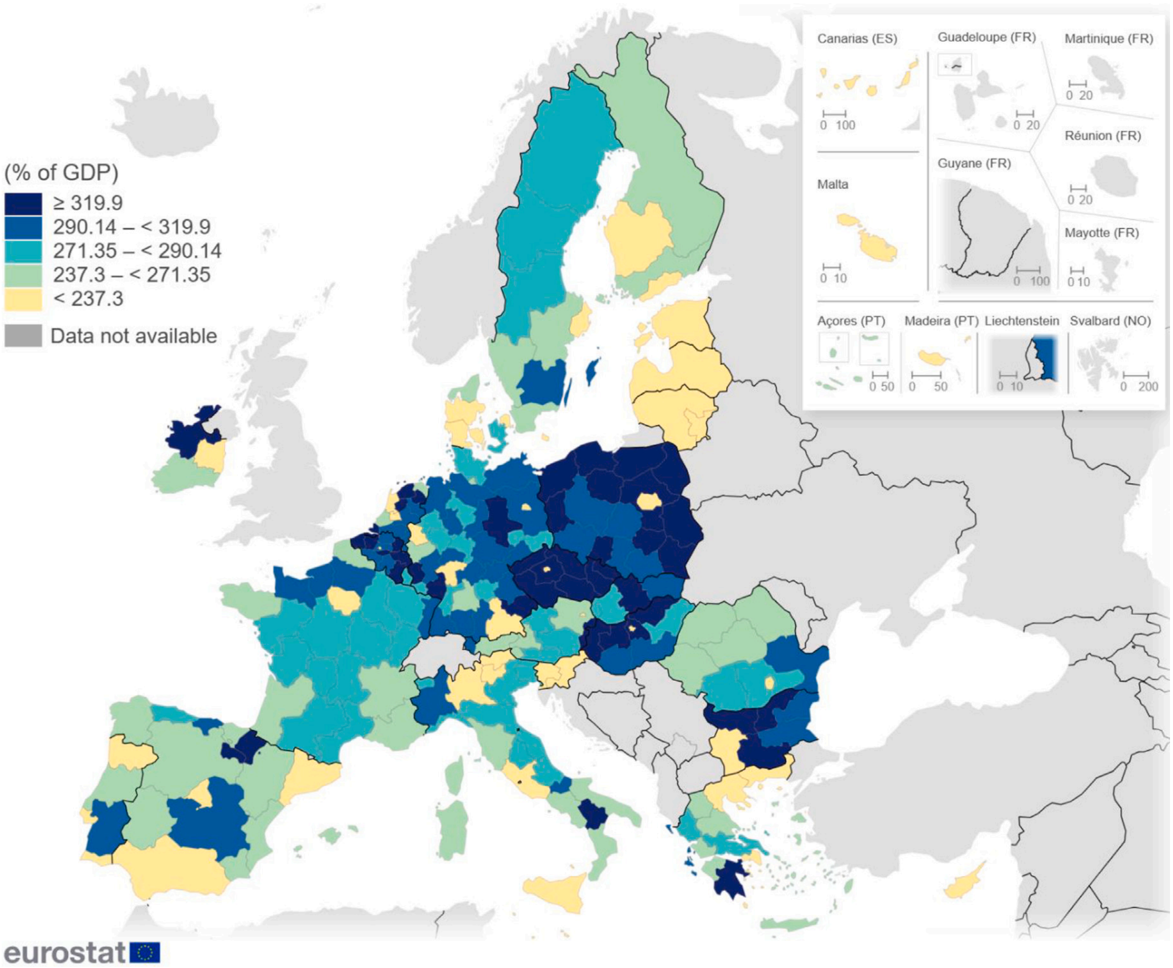

Fig. 2. Total out-of-region trade as a percentage of GDP, in 2017.
Source: Authors' elaboration on RHOMOLO V4 dataset and ARDECO data.

Two core theoretical assumptions guide the empirical setup. First, we assume the existence of conditional convergence: less productive regions are expected to grow faster than more productive ones, provided they share similar structural characteristics. As noted by Barro and Sala-i Martin (2004, p 14), when considering relatively homogeneous economies — such as U.S. states, Japanese prefectures, or European regions — poorer areas tend to catch up over time. Second, consistent with neoclassical and endogenous growth theories, we posit that higher levels of physical and human capital are associated with stronger productivity growth (Mincer, 1984; Lucas, 1988).

We begin by estimating a baseline model in which the dependent variable is the annualised growth rate of regional labour productivity between 2017 and 2023, computed in logarithmic terms. This growth rate is alternatively calculated using two productivity measures: per employee and per hour worked. The key explanatory variables include the initial productivity level, a proxy for physical capital (capital stock per employee), and a proxy for technological capacity (the share of employment in high-tech industries).[3] The baseline specification is as follows:

$$\Delta \text{productivity}_{i,t} = \alpha + \beta_1 * \text{productivity}_{i,t-1} + \beta_2 * \text{physical\_capital}_{i,t-1} + \beta_3 * \text{technology}_{i,t-1} + \varepsilon_{i,t} \quad (1)$$

where:

[3] We also tested for the contribution of human capital, proxied by years of schooling and tertiary educational attainment, but the variables did not yield statistically significant results. This is likely due to their strong correlation with the high-tech employment variable, which, by construction, already captures more skilled labour force.

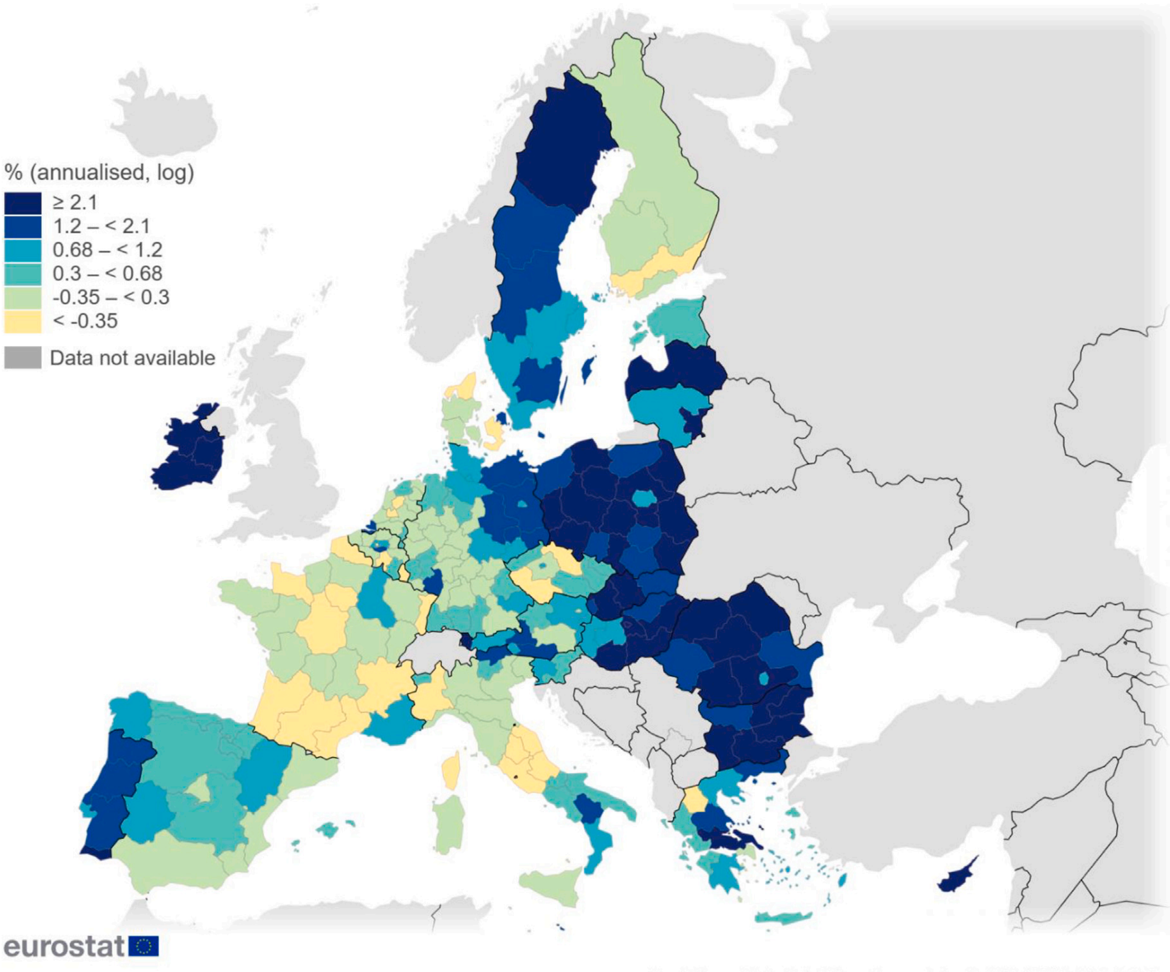

Fig. 3. Change in hour productivity between 2017 and 2023 (annualised, log).
Source: Authors' elaboration on ARDECO data.

- Δproductivity$_{i,t}$ denotes the annualised log-growth rate of productivity (measured, alternatively, per employee and per hours worked) from 2017 to 2023, computed as:

$$\frac{\log(y_{i,t}) - \log(y_{i,t-1})}{6}$$

- productivity$_{i,t-1}$ is the initial productivity level (in 2017), in logs;
- physical_capital$_{i,t-1}$ is the capital stock per employee in 2017[4];
- technology$_{i,t-1}$ measures employment in high-tech sectors as a percentage of total employment.[5]

The sign of β_1 will provide evidence of convergence: a negative coefficient would confirm that less productive regions grew faster during the period, consistent with the conditional convergence hypothesis. β_2 and β_3 are expected to be positive, as regions with stronger physical capital bases and more technologically advanced labour markets are more likely to experience sustained growth. Preliminary tests were conducted to assess the presence of spatial dependencies. However, the results of spatial autocorrelation tests were inconclusive, and thus did not justify the adoption of a spatial econometric specification in the final model.

[4] Regional capital stock in 2017 has been estimated by the authors, relying on Gross Fixed Capital Formation at constant prices as reported in the EU ARDECO dataset and on a yearly discount rate of 10%.

[5] This information is not available for the following regions: Trier, Voreio Aigaio, Notio Aigaio, Dytiki Makedonia, Ipeiros, Thessalia, Ionia Nisia, Peloponnisos, Ciudad de Ceuta, Ciudad de Melilla, Åland, Valle d'Aosta/Vallée d'Aoste, Swietokrzyskie, Algarve, Região Autónoma dos Açores, Região Autónoma da Madeira; which are excluded from our final sample.

We then expand this baseline model by introducing trade variables that capture different aspects of regional integration in national and international markets. The first extension assesses the relationship between total trade exposure and productivity growth, using a trade-to-GDP ratio[6]:

$$\Delta \text{productivity}_{i,t} = \alpha + \beta_1 * \text{productivity}_{i,t-1} + \beta_2 * \text{physical\_capital}_{i,t-1} + \beta_3 * \text{technology}_{i,t-1} + \beta_4 * \text{trade\_tot}_{i,t-1} + \varepsilon_{i,t} \tag{2}$$

This model allows us to test whether regions that are more integrated in terms of trade flows — regardless of direction or partner — experience higher productivity growth. *Trade_tot* is calculated as the sum of exports and imports divided by GDP.

To refine this analysis, we exploit one of the unique advantages of our data: the ability to distinguish between different types of trade linkages, particularly in terms of geography and direction. The next model differentiates trade based on the partner's location, dividing flows into intra-EU and extra-EU categories:

$$\Delta \text{productivity}_{i,t} = \alpha + \beta_1 * \text{productivity}_{i,t-1} + \beta_2 * \text{physical\_capital}_{i,t-1} + \beta_3 * \text{technology}_{i,t-1} + \beta_4 * \text{trade\_share\_eu}_{i,t-1} + \beta_5 * \text{trade\_share\_row}_{i,t-1} + \varepsilon_{i,t} \tag{3}$$

Here, *trade_share_eu* and *trade_share_row respectively* capture the share of trade conducted with EU and non-EU partners. This distinction allows us to test whether the benefits of trade differ depending on the market context—whether regions gain more from integration within the Single Market or from accessing global markets beyond the EU.

In the fourth specification, we decompose trade further by separating exports and imports, again distinguishing between EU and non-EU destinations and origins. This provides insights into whether it is export-led or import-driven activity that is more strongly associated with productivity dynamics, and whether those effects depend on geographic orientation:

$$\begin{aligned}\Delta \text{productivity}_{i,t} = {} & \alpha + \beta_1 * \text{productivity}_{i,t-1} + \beta_2 * \text{physical\_capital}_{i,t-1} + \beta_3 * \text{technology}_{i,t-1} \\ & + \beta_4 * \text{export\_share\_eu}_{i,t-1} + \beta_5 * \text{export\_share\_row}_{i,t-1} \\ & + \beta_6 * \text{import\_share\_eu}_{i,t-1} + \beta_7 * \text{import\_share\_row}_{i,t-1} + \varepsilon_{i,t}\end{aligned} \tag{4}$$

Where:

- *export_share_eu* and *import_share_eu* are respectively the shares of export and import destined to and originating from other regions that belong to the European Union;
- *export_share_row* and *import_share_row* are respectively the shares of export and import destined to and originating from countries outside the European Union.

This model tests whether productivity gains are primarily associated with outward orientation (exports), or with inward flows of goods and services (imports), and whether these effects are symmetric or asymmetric across trade partners.

Finally, we focus on the composition of trade, especially regarding the nature of traded goods. In the last model, we isolate capital goods imports and final goods exports, again distinguishing by trade partner region:

$$\begin{aligned}\Delta \text{productivity}_{i,t} = {} & \alpha + \beta_1 * \text{productivity}_{i,t-1} + \beta_2 * \text{physical\_capital}_{i,t-1} + \beta_3 * \text{technology}_{i,t-1} \\ & + \beta_4 * \text{export\_final\_eu}_{i,t-1} + \beta_5 * \text{export\_final\_row}_{i,t-1} \\ & + \beta_6 * \text{import\_capital\_eu}_{i,t-1} + \beta_7 * \text{import\_capital\_row}_{i,t-1} + \varepsilon_{i,t}\end{aligned} \tag{5}$$

This structure allows us to explore whether productivity growth is more responsive to the acquisition of capital inputs — potentially reflecting technology transfer or production upgrading — or to the development of high-value exports, particularly to more dynamic or differentiated markets outside the EU.

All models are estimated using cross-sectional ordinary least squares (OLS) methods. They are weighted by regional GDP in 2017 in order to account for the heterogeneity in size and economic structure across regions, and robustness is assessed by testing both productivity per employee and per hour worked, ensuring that our findings are not driven by variations in labour intensity or working time. Additionally, we extend the analysis by incorporating a broader set of regional characteristics, capturing institutional, financial and geographical aspects, as well as exogenous shocks, as potential factors conditioning regional productivity dynamics. Overall, this sequential modelling strategy enables us to isolate the role of different dimensions of trade and technology in shaping productivity trajectories across Europe's diverse regional landscape.

5. Results and discussion

We begin our empirical analysis by estimating the baseline model and testing whether the core theoretical predictions of the Barro-type growth framework are supported by our data. Column 1 of Table 1 shows the results for productivity measured in terms of output per hour worked. As expected, the coefficient on the initial level of productivity is negative and statistically significant, suggesting the presence of conditional convergence among EU regions during the 2017–2023 period. In other words, less productive regions have experienced faster productivity growth relative to their more advanced counterparts, consistent with

[6] We exclude five French DOM regions and four Croatian regions, for which trade data is not available, from our final sample.

Table 1
Technology, trade and productivity growth (hours worked) between 2017 and 2023.
Source: Authors.

	M1 Hour productivity growth	M2 Hour productivity growth	M3 Hour productivity growth	M4 Hour productivity growth	M5 Hour productivity growth
Hour Productivity (log)	-1.965***	-1.841***	-1.750***	-1.958***	-1.043***
	(0.31)	(0.29)	(0.30)	(0.30)	(0.26)
Capital Stock	0.010***	0.009***	0.006*	0.006**	-0.005*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
High-tech	0.078**	0.189***	0.035	0.101**	0.005
	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)
Total trade		0.763***			
		(0.14)			
Share of trade with EU			1.901**		
			(0.96)		
Share of trade with ROW			3.776***		
			(0.96)		
Share of export to the EU				2.998***	
				(1.03)	
Share of export to the ROW				4.779***	
				(1.39)	
Share of import from the EU				-3.123**	
				(1.45)	
Share of import from the ROW				-0.534	
				(1.25)	
Export of final goods to the EU					-4.763*
					(2.60)
Export of final goods to the ROW					7.498***
					(2.87)
Import of capital goods from the EU					28.818***
					(6.66)
Import of capital goods from the ROW					24.335***
					(3.79)
Constant	6.266***	3.493***	5.351***	5.986***	3.738***
	(0.84)	(0.95)	(0.88)	(0.87)	(0.76)
Observations	217	217	217	217	217
R^2	0.210	0.300	0.291	0.333	0.535

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

the catch-up dynamics observed in the literature (Barro and Sala-i Martin, 2004; Rodriguez-Pose, 2018). This result validates our choice of a convergence-based specification and aligns with earlier findings on European regional growth dynamics. The other coefficients in the baseline model behave in line with theoretical expectations. Both physical capital (measured as capital stock per employee) and technology (proxied by the share of employment in high-tech sectors) are positively and significantly associated with productivity growth. These findings confirm the role of factor accumulation and technological capability in driving regional economic performance. The significance of the high-tech employment variable also supports the argument that regions embedded in innovation-intensive activities are more likely to experience productivity enhancements over time (Crescenzi et al., 2007; European Commission, 2022).

Moving to Model 2, we introduce total trade openness as an additional regressor—calculated as the sum of exports and imports over regional GDP. The coefficient on trade is positive and statistically significant, reinforcing the view that trade integration is a key determinant of regional productivity dynamics. This echoes well-established theoretical arguments (Grossman and Helpman, 1991; Aghion and Howitt, 1998) and empirical results (e.g., Alcala and Ciccone, 2004), which link trade openness to productivity growth via mechanisms such as increased competition, larger market access, technology transfer, and scale effects. It also aligns with regional-level studies such as Puga (2002) and Mayer et al. (2018), who highlight the productivity-enhancing effects of regional integration within the EU.

In Models 3 and 4, we refine our analysis by differentiating trade by geography and direction. Model 3 includes two variables representing the shares of trade conducted with EU regions and with non-EU partners (“rest of the world”, or RoW). Both trade shares are positively and significantly associated with productivity growth, but the magnitude of the effect is noticeably higher for trade with non-EU regions. This asymmetry offers important insights. First, it supports the hypothesis that extra-EU trade may present greater opportunities for specialisation in high-value-added sectors, as firms face more diverse market conditions and possibly higher levels of demand for innovation and quality (Di Mauro and Forster, 2010). Second, it raises the possibility that trade within the Single Market might be approaching diminishing returns, particularly for mature economies with well-established intra-EU supply chains. The results are also consistent with Brun et al. (2005), who argue that the productivity gains from trade are shaped not only by volume but also by the heterogeneity of trading partners and the complexity of market interactions.

Model 4 decomposes trade into export and import shares with EU and non-EU partners, revealing additional nuances. Here, we find that the share of exports — both to the EU and non-EU countries — is positively and significantly associated with productivity growth. The effect is stronger for extra-EU exports, suggesting that tapping into extra-EU markets may offer greater productivity returns, potentially due to higher competition, more demanding consumers, or better price premiums for high-quality goods (Békés and Murakozy, 2012). On the import side, the results are more mixed. While imports from the rest of the world do not show a significant effect, imports from the EU are negatively associated with productivity growth. This counterintuitive result may reflect a substitution effect where high levels of intra-EU imports, particularly of final goods, crowd out domestic production and reduce incentives for innovation or upgrading. It may also point to structural dependencies on lower-value-added imports or an overreliance on upstream inputs that do not necessarily foster productivity improvements locally.

To further clarify these effects, Model 5 introduces a more granular breakdown of trade by good type and trade direction, distinguishing between imports of capital goods and exports of final goods. This model offers perhaps the most compelling evidence on the mechanisms through which trade influences productivity. Imports of capital goods — especially from outside the EU — are positively and significantly associated with productivity growth. This supports theories of embodied technological transfer, where the importation of advanced machinery or equipment raises the productivity of local production processes (Coe and Helpman, 1995; Keller, 2004). Given the high technological content typically embedded in capital goods, their role in facilitating catch-up and structural transformation is well documented (Crespi and Zuniga, 2012). These results also validate the importance of maintaining open trade channels for machinery and equipment as a means of promoting productivity convergence within Europe.

On the export side, the results show that exports of final goods to non-EU countries are positively associated with productivity growth, while exports of final goods to the EU are negatively associated. The former suggests that firms competing in global markets may be more dynamic and innovative, consistent with the self-selection and learning-by-exporting hypotheses (Melitz, 2003; Loecker, 2007). The latter finding — negative effects of intra-EU final goods exports — may seem surprising at first, but can be explained by considering market saturation and limited growth potential within the Single Market, especially for lower-tech or commodified products. If firms are engaged in price-based competition within the EU, rather than innovation-led differentiation, their productivity gains may be limited.

To further strengthen the solidity of our results and to consider wider regional and national patterns that could affect productivity growth, we expand the basic models by adding extra covariates. These variables aim to capture the institutional, financial and spatial dimensions of development that are not fully reflected in the basic growth model. In particular, we introduce four new controls:

- *Institutional quality*, measured at the regional level and proxied by the European Quality of Government Index (EQI);
- *COVID death – rate*, that is an age-standardised death rate due to COVID-19 at regional level;
- *FDI market integration*, measured as the average of inward and outward foreign direct investment (FDI) flows divided by gross domestic product (GDP) at the country level;
- Urbanisation, represented by a dummy variable (*UrbRur*) distinguishing urban from rural regions.

Including these additional variables allow us to determine whether the main findings, namely conditional convergence and the positive impact of trade openness, remain consistent when institutional and structural variations are taken into account. The extended models, presented in Table 2, strongly confirm the same trends observed previously.

The coefficient of initial productivity remains negative and statistically significant across all specifications, which reinforces the presence of conditional convergence among EU regions. Physical capital and technological intensity continue to have a positive and significant effect on productivity growth, despite the magnitude of the latter declines slightly in the most comprehensive models. Among the new controls, institutional quality emerges as a positive and significant factor in nearly all models, confirming the growing body of literature suggesting that regions with more effective governance frameworks tend to perform better in terms of productivity growth (Rodríguez-Pose and Ganau, 2022; Barbero et al., 2021). As could be expected, a negative and statistically significant relationship with productivity growth is displayed by the death rate from COVID-19. Although this coefficient is modest in size, it demonstrates how health shocks can generate long-lasting economic consequences, exacerbating existing regional disparities and hindering the process of convergence in the most vulnerable areas. The variable of market integration, which is defined at the country level and is intended to capture the broader dynamics of investment flows and global linkages that extend beyond national borders, shows positive and statistically significant results in most of the specifications. However, in the most complete ones, the negative sign possibly reflects a correlation with trade variables, particularly imports of capital goods and exports of manufactured goods, through which much of the foreign investment effect may be channelled. Turning to the urban–rural dimension, the dummy variable displays a negative and significant relationship with productivity growth. This result is consistent with the idea that less urbanised or more peripheral regions have experienced comparatively faster productivity improvements during the period. In line with our convergence framework, this outcome suggests that the process of catching up is not only observable between advanced and lagging regions at the European scale, but also within countries, where more rural and structurally weaker areas are gradually narrowing their productivity gap vis-à-vis large metropolitan economies.

Table 2
Technology, trade and productivity growth (hours worked) between 2017 and 2023 - Extended specifications.
Source: Authors.

	M1 Hour productivity growth	M2 Hour productivity growth	M3 Hour productivity growth	M4 Hour productivity growth	M5 Hour productivity growth
Hour Productivity (log)	-2.556***	-2.423***	-2.412***	-2.674***	-1.744***
	(0.33)	(0.32)	(0.34)	(0.34)	(0.31)
Capital Stock	0.010***	0.010***	0.006*	0.008***	-0.003
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
High-tech	0.172***	0.226***	0.113***	0.151***	0.051
	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)
Institutional quality	0.360***	0.258***	0.374***	0.369***	0.352***
	(0.10)	(0.10)	(0.10)	(0.10)	(0.08)
Covid death rate	-0.001***	-0.001***	-0.001***	-0.001***	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
UrbRur=1	-0.448***	-0.310**	-0.474***	-0.330**	-0.243*
	(0.15)	(0.15)	(0.15)	(0.16)	(0.13)
FDI market integration	0.014*	0.015*	-0.002	-0.000	-0.016*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Total trade		0.485***			
		(0.14)			
Share of trade with EU			-0.278		
			(0.99)		
Share of trade with ROW			3.779***		
			(0.97)		
Share of export to the EU				2.667***	
				(1.01)	
Share of export to the ROW				1.879	
				(1.34)	
Share of import from the EU				-4.527***	
				(1.37)	
Share of import from the ROW				1.853	
				(1.23)	
Export of final goods to the EU					-4.857*
					(2.53)
Export of final goods to the ROW					9.387***
					(3.22)
Import of capital goods from the EU					16.618**
					(6.71)
Import of capital goods from the ROW					22.345***
					(3.61)
Constant	8.525***	6.523***	8.153***	8.950***	6.310***
	(0.94)	(1.10)	(1.03)	(1.04)	(0.94)
Observations	217	217	217	217	217
R^2	0.390	0.419	0.426	0.450	0.603

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

As for trade-related factors, the extended specifications support the reliability of our earlier findings. Regions that are more exposed to international trade continue to experience faster productivity growth, particularly with regard to exchanges beyond the EU. By contrast, intra-EU trade appears to play a more limited role once differences in institutional quality and structural characteristics are taken into account, suggesting that the productivity benefits of integration are increasingly driven by global rather than purely European linkages.

To validate our findings more robustly and ensure that the main results are not influenced by specific modelling assumptions, we conducted additional tests. We first re-estimate all models using productivity per employee rather than per hour worked, allowing us to verify whether the observed relationships are robust to different labour productivity metrics. Overall, the main patterns hold. The base model confirms conditional convergence and the significance of physical capital and technological intensity. The

Table 3
Technology, trade and productivity growth (employees) between 2017 and 2023.
Source: Authors.

	M1 Employee productivity growth	M2 Employee productivity growth	M3 Employee productivity growth	M4 Employee productivity growth	M5 Employee productivity growth
Employee productivity (log)	-2.612***	-2.417***	-2.531***	-2.669***	-2.079***
	(0.38)	(0.38)	(0.39)	(0.40)	(0.36)
Capital Stock	0.012***	0.012***	0.009***	0.010***	0.002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
High-tech	0.148***	0.197***	0.091**	0.117***	0.030
	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)
Institutional quality	-0.029	-0.117	-0.001	-0.026	0.038
	(0.08)	(0.09)	(0.08)	(0.09)	(0.07)
Covid death rate	-0.001*	-0.001**	-0.000	-0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
FDI market integration	0.013*	0.014*	-0.002	-0.000	-0.015*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
UrbRur=1	-0.537***	-0.410***	-0.550***	-0.466***	-0.323***
	(0.14)	(0.14)	(0.14)	(0.15)	(0.12)
Total trade		0.455***			
		(0.14)			
Share of trade with EU			-0.312		
			(0.95)		
Share of trade with ROW			3.588***		
			(0.93)		
Share of export to the EU				0.979	
				(0.98)	
Share of export to the ROW				2.890**	
				(1.31)	
Share of import from the EU				-2.128	
				(1.32)	
Share of import from the ROW				0.746	
				(1.20)	
Export of final goods to the EU					-6.894***
					(2.50)
Export of final goods to the ROW					10.684***
					(3.19)
Import of capital goods from the EU					17.177***
					(6.49)
Import of capital goods from the ROW					17.470***
					(3.56)
Constant	27.456***	23.948***	26.675***	28.066***	22.140***
	(3.92)	(3.98)	(4.06)	(4.12)	(3.73)
Observations	217	217	217	217	217
R^2	0.347	0.376	0.385	0.389	0.545

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

coefficients for institutional quality and FDI market integration, instead, become less stable and lose statistical significance in the more comprehensive specifications, suggesting that, once trade and structural characteristics are controlled for, direct influence of national-level investment dynamics and institutional settings weakens. The effect of total trade on productivity growth remains strong and positive. However, when trade is decomposed by geography and direction, some coefficients lose statistical significance — particularly the positive effects of intra-EU trade shares — while the significance of extra-EU trade remains robust. These shifts could be attributed to the greater variation in hours worked across regions, which affects productivity per employee but not per hour. As such, using per-hour metrics may better isolate efficiency from labour utilisation effects (see Table 3).

Importantly, capital goods imports remain strongly and positively associated with productivity growth in all specifications. This finding is robust across both productivity measures and underscores the central role of technology-embedded capital in driving regional development. The persistent positive association between final goods exports to non-EU countries and productivity growth also holds in the per-employee specification, while the negative coefficient of final exports to EU destinations becomes even more statistically significant. This suggests that productivity dynamics are closely tied to the direction and sophistication of export flows and supports arguments for greater strategic diversification of export markets.

As an additional robustness exercise,[7] we tested whether the main findings were driven by a limited number of outlier regions. Specifically, we sequentially excluded from the sample the five regions[8] displaying the highest levels of productivity and foreign trade intensity and re-estimated the models 2 and 5 using the measure of productivity per hour worked. The results, presented in Appendix, show that the estimated coefficients remain stable in both magnitude and sign, indicating that the relationships identified are not dependent on a few highly performing or trade-intensive regions.

Taken together, these results point to several key conclusions. First, trade openness is consistently associated with regional productivity growth, but the nature and direction of trade flows matter significantly. Regions that are more integrated into global (non-EU) markets appear to reap stronger productivity benefits, likely due to exposure to more competitive and innovation-driven environments. Second, imports of capital goods play a distinct and positive role in regional upgrading, reinforcing the case for policies that facilitate access to productivity-enhancing machinery and technology. Third, the benefits of intra-EU trade — long emphasised as a driver of integration — may now be more modest in terms of productivity, especially for exports of standardised final goods.

These findings carry important policy implications. EU cohesion and regional development policy might consider placing more emphasis on promoting global competitiveness, not only through access to foreign markets but also through incentives for innovation and technology adoption. For example, facilitating the importation of advanced capital goods — particularly by lagging regions — may provide a more targeted strategy for stimulating productivity convergence. At the same time, regional trade strategies should prioritise value-added exports beyond EU borders, enabling firms to access larger and more dynamic markets where innovation is more highly rewarded.

Lastly, our results contribute to the ongoing debate on the geography of trade and growth in the EU. While much of the literature has focused on national-level trade effects, our regional analysis highlights that trade dynamics operate at a more granular scale. Differences in regional specialisation, factor endowments, and institutional capabilities mean that not all regions benefit equally from trade. As such, policy tools — whether at national or EU levels — need to account for spatial heterogeneity in designing interventions that support productivity and long-term growth.

6. Conclusion

This paper examined the determinants of regional productivity growth in Europe between 2017 and 2023, focusing on the roles of technology and trade. Grounded in the Solow growth framework and Barro-type regressions, our analysis provides robust evidence that both factor endowments and external linkages shape the productivity trajectories of European regions.

We confirm the presence of conditional convergence across European regions: less productive areas grew faster over the following six years, consistent with catch-up dynamics among structurally similar economies. This pattern, observed for both productivity per hour and per employee, supports the neoclassical prediction that regions with lower initial productivity tend to converge. Beyond this mechanism, physical capital and high-tech employment are strong internal drivers of productivity growth, confirming the traditional view that investments in capital accumulation and technological capability form the bedrock of long-term productivity improvement. The role of high-tech employment, in particular, suggests that regions embedded in knowledge-intensive sectors are better positioned to generate and absorb innovation, enabling them to sustain higher productivity growth. This has clear policy implications: supporting technological specialisation and expanding access to human capital-intensive sectors may be one of the most effective strategies for regional development.

The main contribution of our study lies in the detailed exploration of trade and its effects on regional productivity. We find a significant positive association between total trade exposure and productivity growth. This supports a long-standing body of work linking trade openness to higher efficiency through competition, access to foreign technology, and market scale effects. Yet, this positive relationship masks important heterogeneity depending on the *direction* and *composition* of trade. Disaggregating trade by geography shows that while both intra-EU and extra-EU trade are positively correlated with productivity growth, the effect is stronger for extra-EU trade. This asymmetry persists even when controlling for a region's initial productivity, capital intensity, and technological base, suggesting that access to non-EU markets — often more diverse, competitive, and fast-growing — provides greater incentives for regional economic upgrading. This aligns with the argument that trade with non-EU partners exposes firms to more dynamic demand structures and competitive pressures, driving innovation and productivity gains.

Delving deeper into the structure of trade, we uncover more nuanced insights. Export composition appears particularly important: regions with a higher share of extra-EU exports tend to grow faster in terms of productivity. In contrast, exports to EU countries are not associated with comparable benefits and, in some specifications, are even negatively associated with productivity growth. This may reflect market saturation or intense price competition within the EU Single Market, especially for regions specialising in lower value-added goods. Conversely, competing in global markets likely requires higher quality standards and product differentiation, thus incentivising productivity-enhancing investments. Similarly, the role of imports varies sharply by type and origin. While aggregate

[7] We also tested the models for the 2017–2019 sub-period, stopping before the COVID-19 pandemic to avoid distortions in trade and productivity dynamics. However, the results are not reported here, as the short time span yields statistically weak and inconclusive estimates, likely reflecting limited variation over such a brief period.

[8] The five regions sequentially excluded from the robustness test correspond to those exhibiting the highest levels of productivity and international trade intensity: Cyprus (CY00), Southern (IE05) and Eastern and Midland (IE06) in Ireland, Luxembourg (LU00), and Malta (MT00).

import shares show mixed effects, imports of capital goods—particularly from outside the EU—are positively and significantly associated with productivity growth. This finding is consistent with theories of embodied technology transfer, whereby capital goods serve as carriers of foreign knowledge and innovation (Coe and Helpman, 1995). The ability to access and effectively utilise these productivity-enhancing imports appears to be a key factor in regional convergence. It also suggests that trade policy and industrial strategy should not only prioritise export growth but also ensure that firms have access to sophisticated foreign inputs, especially in lagging regions.

The inclusion of institutional and structural variables strengthens these conclusions. Regions with higher institutional quality tend to perform better in terms of productivity growth, which confirms that the effectiveness of governance shapes the ability to exploit opportunities in terms of trade and technology. Similarly, the negative impact of the death rate from the pandemic illustrates how exogenous shocks can exacerbate regional disparities. Meanwhile, the stronger performance of rural or less urbanised regions points to ongoing convergence processes even within countries.

Importantly, these patterns hold across both productivity measures — per employee and per hour worked — suggesting that they are not artefacts of variation in labour intensity or working time. Rather, they reflect deeper economic structures and institutional capacities that condition how regions integrate into global value chains. In this sense, our findings bridge the literature on regional growth and the increasingly important field of global production networks, offering a spatial perspective on how trade composition shapes development outcomes.

From a policy perspective, several conclusions emerge. First, while European integration has undoubtedly fostered cohesion, its productivity-enhancing potential seems to have plateaued in some areas. Policies that facilitate extra-EU trade — particularly in high-value final goods — could provide new engines of regional productivity. Export diversification strategies, trade facilitation measures, and export credit support targeted at non-EU markets may all be beneficial in this regard. Second, the strong link between capital goods imports and productivity growth highlights the importance of technology diffusion through trade. Regional development policies should not focus solely on generating innovation but also on its absorption — lowering barriers to importing capital goods, reducing tariffs on machinery, and supporting firms' investment in technology adoption. Complementary measures — such as training, digital readiness, or local R&D—can amplify these effects. Third, our findings underline the need for tailored regional policies. The same trade strategy may not benefit all regions equally. While some regions have the absorptive capacity to capitalise on extra-EU trade and technology-intensive imports, others may lack the infrastructure, skills, or institutional conditions required. A place-based approach, as advocated by the European Commission (2022), is therefore essential to ensure that trade and technology policies translate into inclusive regional growth.

Methodologically, the study also highlights the value of integrating disaggregated trade data into regional growth models. Distinguishing trade by geography, direction, and good type reveals dynamics that aggregate indicators obscure. Still, several limitations remain. The 2017–2023 timeframe includes major shocks that may have influenced trade and productivity patterns, supply chains, and productivity performance in ways that are not fully captured by our models. Moreover, while we treat trade as a determinant of productivity, reverse causality is possible: more productive regions may engage more in extra-EU trade. Future work could address these issues using instrumental variables or dynamic modelling, as well as exploring updated data to assess persistence.

Despite these caveats, the evidence suggests that regional productivity growth in Europe is not solely a function of internal factor accumulation or technological specialisation. Rather, it is increasingly shaped by how regions connect to external markets and global production systems. Trade — especially in capital goods and high-value exports to non-EU markets — acts as a conduit for knowledge, competition, and investment, supporting not just growth, but also convergence in productivity across Europe's diverse regional landscape.

CRediT authorship contribution statement

Alberto Tidu: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Luigi Apuzzo:** Writing – original draft, Formal analysis, Data curation. **Stefano Usai:** Writing – review & editing, Writing – original draft, Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Alberto Tidu reports financial support was provided by European Union. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table A.1
Robustness check (hour productivity): models (2) and (5) excluding IE05, IE06, LU00, MT00, and CY00.
Source: Authors.

	w/o IE05		w/o IE06		w/o LU00		w/o MT00		w/o CY00	
	Model 2	Model 5	Model 2	Model 5	Model 2	Model 5	Model 2	Model 5	Model 2	Model 5
Hour Productivity (log)	-2.0202***	-1.6609***	-2.7287***	-1.9328***	-2.3803***	-1.7066***	-2.4230***	-1.7318***	-2.4164***	-1.7208***
	(0.298)	(0.304)	(0.301)	(0.307)	(0.320)	(0.306)	(0.326)	(0.307)	(0.327)	(0.307)
Capital Stock	0.0022	-0.0043	0.0120***	-0.0003	0.0102***	-0.0025	0.0100***	-0.0029	0.0100***	-0.0028
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
High-tech	0.1948***	0.0648**	0.1333***	0.0265	0.2242***	0.0517	0.2254***	0.0509	0.2263***	0.0499
	(0.035)	(0.032)	(0.038)	(0.032)	(0.038)	(0.032)	(0.039)	(0.032)	(0.039)	(0.032)
Institutional quality	0.3617***	0.3783***	0.3313***	0.3687***	0.2352**	0.3296***	0.2581***	0.3504***	0.2576***	0.3543***
	(0.090)	(0.082)	(0.091)	(0.081)	(0.097)	(0.083)	(0.099)	(0.083)	(0.099)	(0.083)
Covid death rate	-0.0007**	-0.0002	-0.0012***	-0.0005*	-0.0012***	-0.0004	-0.0012***	-0.0003	-0.0012***	-0.0003
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI market integration	0.0089	-0.0178**	0.0112	-0.0113	0.0396***	-0.0036	0.0150*	-0.0183**	0.0138	-0.0239**
	(0.007)	(0.008)	(0.007)	(0.008)	(0.012)	(0.011)	(0.008)	(0.009)	(0.009)	(0.011)
UrbRur=1	-0.2811**	-0.2374*	-0.0502	-0.1364	-0.3210**	-0.2441*	-0.3110**	-0.2299*	-0.3096**	-0.2344*
	(0.138)	(0.125)	(0.145)	(0.129)	(0.151)	(0.126)	(0.153)	(0.127)	(0.153)	(0.127)
Total trade	0.3804***		0.3909***		0.5140***		0.4853***		0.4919***	
	(0.132)		(0.133)		(0.143)		(0.145)		(0.148)	
Export of final goods to the EU		-5.0484**		-4.6457*		-5.6064**		-5.1144**		-4.6759*
		(2.497)		(2.480)		(2.554)		(2.538)		(2.534)
Export of final goods to the ROW		10.9684***		7.0318**		12.0848***		10.6705***		10.7166***
		(3.231)		(3.243)		(3.546)		(3.385)		(3.407)
Import of capital goods from the EU		16.9277**		17.5661***		19.1706***		17.3195**		16.0584**
		(6.614)		(6.577)		(6.828)		(6.727)		(6.720)
Import of capital goods from the ROW		14.9353***		19.6233***		18.7737***		21.5748***		21.6353***
		(4.519)		(3.639)		(4.113)		(3.660)		(3.655)
Constant	6.1333***	6.1387***	7.8739***	6.8945***	6.2425***	6.0647***	6.5206***	6.2553***	6.4793***	6.2033***
	(0.991)	(0.926)	(1.025)	(0.936)	(1.087)	(0.942)	(1.101)	(0.937)	(1.117)	(0.941)
Observations	216	216	216	216	216	216	216	216	216	216
R^2	0.4521	0.5522	0.4516	0.5697	0.4363	0.6073	0.4182	0.6053	0.4162	0.6037

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Appendix. Robustness check

See Table A.1.

References

Aghion, P., Howitt, P., 1998. first ed. Endogenous Growth Theory, vol. 1, The MIT Press.
Alcala, F., Ciccone, A., 2004. Trade and productivity. Quaterly J. Econ. 119, 613–646.
Barbero, J., Mandras, G., Rodríguez-Crespo, E., Rodríguez-Pose, A., 2021. Quality of government and regional trade: evidence from European union regions. Reg. Stud. 55, 1240–1251.
Barro, R.J., 1996. Determinants of economic growth: A cross-country empirical study.
Barro, R.J., 2004. Economic Growth. MIT Press, Chapter Determinants of Economic Growth.
Barro, R.J., Sala-i Martin, X., 1991. Convergence across states and regions. Brook. Pap. Econ. Act. 22, 107–182.
Barro, R.J., Sala-i Martin, X., 2004. Economic Growth, second ed. MIT Press, p. 654.
Barry, F., Bradley, J., 1997. FDI and trade: The irish host-country experience. Econ. J. 107, 1798–1811.
Bauer, P., Fedotenkov, I., Genty, A., Hallak, I., Harasztosi, P., Martinez, D., Nguyen, T.D., Preziosi, N., Rincon-Aznar, A., Martinez, M.S., 2020. Productivity in Europe - Trends And Drivers in a Service-Based Economy. Technical Report, JRC.
Békés, G., Murakozy, B., 2012. Temporary trade and heterogeneous firms. J. Int. Econ. 87, 232–246.
Bhalla, S., 2002. Imagine There's No Country: Poverty, Inequality, and Growth in the Era of Globalization. Peterson Institute for International Economics, Washington, DC.
Breinlich, H., 2006. The spatial income structure in the European union - What role for economic geography? J. Econ. Geogr. 6, 593–617.

Brun, J.F., Combes, J.L., Renard, M.F., 2005. Are there spillover effects between coastal and non-coastal regions in China ? China Econ. Rev. 16, 133–153.
Buch, C.M., Toubal, F., 2007. Openness and growth: The long shadow of the Berlin wall. J. Macroecon. 31, 409–422.
Castellani, D., Serti, F., Tomasi, C., 2010. Firms in international trade: Importers' and exporters' heterogeneity in Italian manufacturing industry. World Econ. 33, 424–457.
Coe, D.T., Helpman, E., 1995. International R&D spillovers. Eur. Econ. Rev. 39, 859–887.
Crescenzi, R., Rodríguez-Pose, A., Storper, M., 2007. The territorial dynamics of innovation: a Europe-United States comparative analysis. J. Econ. Geogr. 7, 673–709.
Crespi, G., Zuniga, P., 2012. Innovation and productivity: Evidence from six Latin American countries. World Dev. 40, 273–290.
Di Mauro, F., Forster, K., 2010. Globalisation and the competitiveness of the Euro area. In: MEF Working Papers N° 5.
European Commission, 2022. EU Regional Competitiveness Index 2.0 2022. Technical Report, Publications Office of the European Union.
Garcia-Rodriguez, A., Lazarou, N.J., Mandras, G., Salotti, S., Thissen, M., Kalvelagen, E., 2023. A NUTS-2 European union interregional system of social accounting matrices for the year 2017: The RHOMOLO V4 dataset.
Grossman, G., Helpman, E., 1991. first ed. Innovation and Growth in the Global Economy, vol. 1, The MIT Press.
Hilson, M., 2008. The Nordic model : Scandinavia since 1945. Reaktion Books Ltd, p. 234.
Keller, W., 2004. International technology diffusion. J. Econ. Lit. 42, 752–782.
Krugman, P., 1991. Increasing returns and economic geography. J. Political Econ. 99 (3), 483–499.
Krugman, P., Elizondo, R.L., 1996. Trade policy and the third world metropolis. J. Dev. Econ. 49 (1), 137–150, Increasing Returns, Monopolistic Competition and Economic Development.
Laurin, F., 2012. Trade and regional growth in Spain: panel cointegration in a small sample. Appl. Econ. 44, 435–447.
Leong, C.K., 2013. Special economic zones and growth in China and India: an empirical investigation. Int. Econ. Econ. Policy 10, 549–567.
Loecker, J.D., 2007. Do exports generate higher productivity? Evidence from Slovenia. J. Int. Econ. 73, 69–98.
Lucas, R.E., 1988. On the mechanics of economic development. J. Monet. Econ. 22, 3–42.
Mayer, T., Vicard, V., Zignago, S., 2018. The cost of Non-Europe, revisited.
McCallum, J., 1995. National borders matter: Canada-U.S. regional trade patterns. Am. Econ. Rev. 85, 615–623.
Melitz, M., 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. Econometrica 71, 1695–1725.
Mincer, J., 1984. Human capital and economic growth. Econ. Educ. Rev. 3, 195–205.
Mo, J., Qiu, L.D., Zhang, H., Dong, X., 2021. What you import matters for productivity growth: Experience from Chinese manufacturing firms. J. Dev. Econ. 152.
Nitsch, V., 2000. National borders and international trade: evidence from the European union. Can. J. Econ./Revue Can. D'Économique 33, 1091–1105.
OECD, 2021. Regional Outlook 2021: Slovak Republic. Technical Report, OECD Publishing.
Paluzie, E., 2001. Articles: Trade policy and regional inequalities. Pap. Reg. Sci. 80 (1), 67–85.
Petrakos, G., Economou, D., 2003. The spatial aspects of development in south-eastern Europe. Spatium 10, 1–13.
Puga, D., 2002. European regional policies in light of recent location theories. J. Econ. Geogr. 2, 373–406.
Resmini, L., 2020. Openness and regional growth. Sci. Reg. 19, 395–430.
Rodríguez-Pose, A., 2013. Do institutions matter for regional development? Reg. Stud. 47, 1034–1047.
Rodriguez-Pose, A., 2018. The revenge of the places that don?t matter (and what to do about it). Camb. J. Reg. Econ. Soc. (1805).
Rodríguez-Pose, A., Ganau, R., 2022. Institutions and the productivity challenge for European regions. J. Econ. Geogr. 22, 1–25.
Romer, P., 1990. Endogenous technological change. J. Political Econ. 98, S71–102.
Santamaría, M., Ventura, J., Yeşilbayraktar, U., 2023. Exploring European regional trade. J. Int. Econ. 146.
Solow, R., 1956. A contribution to the theory of economic growth. Q. J. Econ. 70, 65–94.
Sun, H., Hone, P., Doucouliago, H., 1999. Economic openness and technical efficiency: A case study of Chinese manufacturing industries. Econ. Transit. 7, 615–636.
Traistaru, I., Nijkamp, P., Longhi, S., 2002. Regional specialization and employment dynamics in transition countries. Reg. Stud. 36, 225–241.
Venables, A.J., 2003. Winners and losers from regional integration agreements. Econ. J. 113, 747–761.