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On the road to regional 'Competitive Environmental Sustainability': the role of the European structural funds

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Abstract

We construct a novel indicator of regional competitive sustainability based on the changes over time of employment sectoral shares across all the regions of the European Union. The indicator accounts for shifts in employment towards greener and more productive sectors over the 2008-2018 period. The mapping of the indicators shows considerable regional heterogeneity in terms of both competitiveness and environmental sustainability, as well as interesting dynamics over time. We present an econometric analysis of the determinants of these sectoral shifts. It appears that the European Structural Funds are positively associated with the transition towards a more competitive and sustainable economy at the regional level. This is particularly true for the competitive dimension of the transition, with the Funds being positively associated with regional employment restructuring towards more productive sectors within each country.

JEL Codes: R11, L16, H25, O52.

Keywords: Green transition, public support, sectoral employment, European regions.

1. Introduction

The Covid-19 outbreak drastically affected the European Union (EU) economies, leading to a GDP contraction in 2020, which was higher than the one caused by the 2008/2009 economic crisis (Chen et al., 2020; Juergensen et al., 2020). Mobility restrictions, lockdown and confinement measures, and other stringent governmental actions to stop disease spread, affected everyday life and work, and changed consumers' behaviour and preferences. For instance, they accelerated the adoption of digital technologies by companies and households in times of physical distancing (Härmand, 2021). Moreover, and despite the crisis being to some extent a symmetric shock, there has been considerable heterogeneity in the economic impact across the countries and regions of the EU (Conte et al., 2020; Sakkas et al., 2021).

The Covid-19 crisis hit when the EU governments were concentrating on growth and development strategies based on the so-called competitive sustainability paradigm: "Competitive sustainability has always been at the heart of Europe's social market economy and should remain its guiding principle for the future" (European Commission, 2019a:3).[1] This included measures to fight climate change, as well as a commitment to maintain welfare levels, and innovative and competitive economic systems. This influenced the Next Generation EU recovery package, which in principle promotes green and digital activities so to permit to achieve the objective of a climate-neutral economy by 2050 (Pfeiffer et al., 2021).

New market trends and needs associated to the green transition, which already started before the pandemic and possibly accelerated due to it, affect the way in which the factors of production are used, and make employment and other resources shift across sectors. These industrial transitions may be costly for certain regions due to the existence of barriers to investment activities, infrastructure gaps, lack of business innovation, and unavailability of people with the appropriate skills. All these factors may impede a smooth transition towards a competitive and greener economy. Furthermore, these macro-economic conditions make some regions less attractive to foreign investors. Consequently, the regions struggling with these long-term challenges are at risk of industrial decline, significant job losses in some sectors, and possibly even outflows of workers.

This papers contributes to a better understanding of how macro-economic conditions, innovation, and European policies such as Cohesion policy regional structural funds have supported and influenced changes in employment across different sectors in the EU regions over the last decade. This constitutes not only a scientific advancement, and it is also relevant for the design of policy

[1] The concept of system innovation explored by the OECD (Diercks, 2019) is similar to that of competitive sustainability used in the EU policy context.

instruments to implement the green transition, including the ongoing policy efforts like the European Green Deal and the Fit for 55 package in the EU (European Commission, 2019b).

Therefore, this paper proposes a new regional indicator able to measure the transition towards a more competitive and environmental sustainable economy constructed using data on sectoral employment, productivity, and greenhouse gas emissions. This indicator provides information on the sectoral changes in the regional economies of the EU[2] along two dimensions, which are of interest both separately and jointly. After having constructed the indicator, and having investigated its distribution at the NUTS 2 level, we use an econometric model to identify what affected the transition towards competitiveness and environmental sustainability as measured by the proposed indicator itself between 2008 and 2018. Among the potential determinants of it, we pay particular attention to the role played by the EU regional funds. We first show that the Cohesion policy investments mainly targeted the regions lagging behind in terms of competitiveness according to the historical values of the indicator we constructed. Then, the econometric investigation suggests that the structural funds are positively related to a transition towards a more competitive and at the same time more environmentally sustainable economy, mainly due to the positive impact on the competitive dimension.

Our study innovates on the existing literature in several ways. First, most of the existing contributions focus on productivity when studying industrial transitions across sectors (usually using highly aggregated sectors like agriculture, industry and services - see, among others, Duernecker et al., 2017; McMillan et al., 2014; Herrendorf et al., 2014; and Dabla-Norris et al., 2013). Besides relying on more sectorally disaggregated data, our indicator uses two dimensions to measure the extent of the economic transition: one based on productivity to account for competitiveness, and a second one based on greenhouse gas emissions to account for environmental sustainability.

Second, the vast majority of the existing evidence is based on country-level data, while in our analysis we use regional (NUTS 2) data. Third, we focus on the role of public policies and innovation investments in supporting the transition towards a greener and competitive economy, a dimension which has been overlooked so far due to the fact that the literature mostly focuses on secular shifts across macro-sectors, rather than medium-term changes as we do in our paper (one notable exception is constituted by Martins, 2019).

The rest of the paper is organised as follows. Section 2 provides a review of the literature on structural transformation across economic sectors. Section 3 describes the regional competitive sustainability indicator. Section 4 assesses the determinants of the transition towards a more competitive and

[2] From now onwards, EU stands for EU27, without the UK.

environmental sustainable economy. Finally, Section 5 concludes and provides policy recommendations.

2. Literature review

Structural transformation, that is the reallocation of the economic activity across sectors, is inherent to modern economic growth (Herrendorf et al., 2014). There are numerous studies in the literature documenting the shifts over time across the three broad sectors of agriculture, manufacturing, and services, with the work by Kuznets (1973) often seen as seminal in showing the decreasing importance of agriculture in favour of manufacturing accompanying economic development. As observed by Dabla-Norris et al. (2013), economic theory usually identifies demand-side and supply-side economic mechanisms driving the observed reallocation of economic activity across sectors. Multi-sector models normally concentrate on the former, which include preferences and income effects (Echevarria, 2000; Kongsamut et al., 2001); an alternative group of models emphasizes supply-side factors like relative price effects to explain the sectoral reallocation of resources. Like "relative price effects" and sectoral shifts are assumed to be driven either by different rates of productivity growth (Duarte and Restuccia, 2010), or by different sectoral capital intensity (Acemoglu and Guerrieri, 2008).

Van Neuss (2018) reviews the literature on the drivers of structural transformation and identifies them as related to income, prices, the input-output relationships in the economy, and the existence of trade-related comparative advantages. The author (p. 26) points out that "it is noteworthy that the recent literature on structural change has been exceptionally silent on policy issues." This stems from the assumption of the transformation process leading to an efficient equilibrium by construction, thus eliminating any role for public policies. However, this view ignores that the process may be not linear due to the existence of rigidities such as, for example, imperfect mobility of the factors of production and environmental and social externalities. Our study aims at filling this gap in the literature by investigating the potential role played by industrial policies like those supported by the European structural funds.

Most of the empirical literature investigates what drives structural change concentrating on the standard determinants of economic growth, by employing data for a large number of both developed and developing countries. For example, MacMillan et al. (2014) use data from 1990 to 2005 on 29 developing countries and 9 developed ones and find that structural change can improve productivity performance in the presence of comparative advantages in non-primary products, when currencies are undervalued (therefore boosting competitiveness), and with flexible labour markets. Martins (2019) finds that both human and physical capital played a key role in shaping structural transformation based on data for 169 countries between 1991 and 2013.

Despite being close in spirit to the literature on structural change, our study differs both because of its territorial focus on regions rather than countries, and for the focus on public policies. Pontikakis et al. (2020) lay out a theory grounded on the territorial dimension of industrial transition seen from a policy point of view and highlight how publicly supported innovation, in a broad sense, may help regional economies in the EU to increase their competitiveness, while at the same time moving towards climate neutrality. The potential role played by innovation for the regional sectoral shifts considered here is also linked to the Schumpeterian theories put forward by Perez (2010) and, for Europe in particular, by Mazzucato and Perez (2015).

3. The regional competitive environmental sustainability indicator

3.1. Constructing the indicator

We construct the Regional Competitive Environmental Sustainability (*RCES*) indicator using NUTS 2 level data from 2008 to 2018 for 56 NACE economic activities (see list in Table A1 in Appendix A).[3] In each year, each economic sector is classified according to its relative positioning in terms of i) competitiveness and ii) environmental sustainability, as follows:

i) "High (Low) productivity" if the productivity of the economic sector is above- (below)-average within the country. Productivity is proxied by wages and salaries per employee, since information on gross value added (GVA) or other output measures are not available with the required degree of NUTS 2 and NACE 2-digits granularity.[4]

ii) "Low (High) emissions intensity" if the air emissions intensity (greenhouse gases emissions – GHG – per employee) of the economic sector is below- (above)-average within the country.[5]

We define the sum of employment in activities that are simultaneously classified as "High productivity" and "Low emissions" as regional employment in competitive and environmental sustainable activities ($Empl_{i,t}^{CompSust}$). Every year, the *RCES* indicator proposed here measures the

[3] The choice of the time period is due to data availability for air emissions. At the time of the study (first quarter of 2022), the latest available data on emissions from JRC-EDGAR were those of 2018.

[4] As a sensitivity analysis, and using industry-country-level data, we analysed the relationship between wage per employee and gross value added per employee. The correlation between the two is extremely high (see Figure D1 in Appendix D), suggesting that using wage per employee as a proxy for productivity is a viable strategy for the present analysis. Using wages rather than GVA also eliminates the problem of dealing with the negative values of GVA, which could exist when intermediate consumption is higher than the value of output.

[5] We decided to express emissions intensity using employment instead of GVA due to the lack of adequate regional data, and because employment is less sensitive to economic shocks than other economic indicators. Moreover, using employment avoids having to deal with negative air emissions intensity when GVA is negative.

proportion of employees working in those competitive and environmental sustainable NACE 2-digits sectors with respect to total employment in each region, as per equation (1):

$$RCES_{i,t} = \frac{Empl_{i,t}^{CompSust}}{Empl_{i,t}^{Total}}, \quad (1)$$

where i refers to NUTS 2 regions, and t refers to years (from 2008 to 2018). $Empl_{i,t}^{CompSust}$ stands for the number of employees in sectors which are simultaneously more productive than the country average, and less intensive than the average in terms of air emissions; and $Empl_{i,t}^{Total}$ stands for the total number of employees in each region. Monetary values are transformed in constant prices using the country GDP deflators (base 2015). The two dimensions, competitiveness and environmental sustainability, have the same weight in the indicator.

Besides its regional distribution, we are interested in the evolution over time of the *RCES* indicator. An increase over time for a certain region would mean that more of the workers located there would find themselves in sectors which are simultaneously more competitive (above average in terms of productivity), and also more environmentally sustainable (below average in terms of air emission intensity). Accordingly, and as shown by equation (2), *RCES Transition* ($RCEST_{i,t}$) measures the change over time in the share of competitive environmental sustainable employment.

$$RCEST_{i,t} = \frac{Empl_{i,t}^{CompSust}}{Empl_{i,t}^{Total}} - \frac{Empl_{i,t-1}^{CompSust}}{Empl_{i,t-1}^{Total}} \quad (2)$$

In our analysis we use the *RCES* indicator as well as two alternative ones based on each of its two components: i) the *RC* indicator refers to the indicator constructed using the information on competitiveness / productivity only; ii) the *RES* indicator refers to the environmental sustainable dimension and it is constructed using solely the information on emissions intensity. By applying equation (2), the change over time of the two components of the *RCES* indicator can be calculated in order to obtain *RCT* and *REST* for competitiveness and sustainability, respectively.

3.2. Data source

We construct the *RCES* indicator using data from Eurostat's "Regional Structural Business Statistics" and "Regional economic accounts", and JRC-EDGAR (Crippa et al., 2021) for air emissions as described below.

3.2.1. Regional data on employment and wages and salaries

Regional data on employment and wages and salaries are extracted from the Regional structural business statistics (NACE B-S) and the Regional economic accounts (NACE A) of Eurostat.

Eurostat data on "Regional Structural Business Statistics" are in different NUTS classifications (2006, 2010, 2013, and 2016). We use the NUTS Converter developed by Batista e Silva et al. (2020) to homogenize the data. The conversion is straightforward for the regions with different NUTS codes but with the same geographical boundaries. When two regions are merged into one, the data for the two are aggregated. However, the procedure is not straightforward when a region gets split in two, or when its physical boundaries change. In those cases, the converter tool uses a population grid with the number of residents in 2011 to calculate the population in each region for the different NUTS classifications, and population shares are used to convert the data.

For the NACE code A sector (Agriculture, forestry and fishing), since data on wages and salary are not available at the NUTS 2 level, we converted the value of compensation of employees into wages and salaries based on the country-industry relationship between the two variables (compensation of employees is the sum of wages and salaries and employers' social contributions).

Missing values in the time series for some variables (employment and wages and salaries) were interpolated.

3.2.2. Region-sector data on GHG emissions

The JRC-EDGAR database (https://edgar.jrc.ec.europa.eu/) contains the annual sector-specific gridmaps with the values of emissions for the three main greenhouse gases (CO2, CH4 and N2O) for the period 1970-2018. Emission gridmaps are expressed in tonnes and classified by sectors using the IPCC 1996 and 2006 codes. Those sectors are different from the NACE classification, therefore we used a the mapping reported in Table A1 to attribute the emissions data to the NACE sectors. The 10 NACE activities in Table 1 account for more than 80% of the GHG in EU27. For the remaining NACE activities associated with manufacturing and services, we used the JRC-EDGAR data for GHG emissions of combustion for manufacturing and energy for buildings, respectively.

To estimate the region-year GHG emissions for all the NACE activities in Table A1, we combined country-industry-year data from ESTAT on the air emissions accounts by NACE Rev. 2 activity [env_ac_ainah_r2] and the estimated regional shares of these emissions from JRC-EDGAR. The CH4 and N2O were also transformed in CO2 equivalent, considering that 1 kg of nitrous oxide (N2O) emissions is equivalent to 298 kg of CO2, and 1 kg of methane (CH4) is equivalent to 25 kg of CO2.

Table 1. Correspondence between NACE activities and IPCC sector (main polluters)

NACE Classification		GHG	IPCC Sector
A	Agriculture, forestry and fishing	15.1%	Enteric fermentation, manure management, agricultural waste burning and agricultural soils
C19	Manufacture of coke and refined petroleum products	4.1%	Oil refineries and transformation industry
C20	Manufacture of chemicals and chemical products	4.7%	Chemical processes and solvents and products use
C23	Manufacture of other non-metallic mineral products	5.9%	Non-metallic minerals production
C24	Manufacture of basic metals	5.0%	Steel production + non-ferrous metals production
D	Electricity, gas, steam and air conditioning supply	29.0%	Power industry, energy for buildings and fuel exploitation gas
E	Water supply; sewerage, waste management and remediation activities	4.7%	Solid waste landfills, solid waste incineration and waste water handling
H49_53	Land transport and transport via pipelines (H49) + Postal and courier activities (H53)	5.6%	Road transportation no resuspension, railways, pipelines and off-road transport
H50	Water transport	4.2%	Shipping
H51	Air transport	4.2%	Aviation (climbing, descent, cruise, landing and takeoff)
	TOTAL	82.6%	

Source: Own elaboration.

Note: Values of GHG refer to the contribution of each NACE activities to the total GHG in E27 for the year 2018. Data extracted from EUROSTAT.

Regional emissions from the JRC-EDGAR emission gridmaps are calculated by computing the sum of emissions of the raster cells that intersect the NUTS-2 polygons, weighting each cell by the coverage fraction of the polygons. NUTS-2 polygons are obtained from Eurostat GISCO. When an emission cell contains both land and water, all the emissions are attributed to the region. The extraction has been performed using the *exactextractr* package for the *R* programming language. Regional shares of emissions are calculated as the shares of regional emissions over total country emissions.

3.3. Analysis of the RCES, RC, and RES indicators

Table 2 displays the unweighted averages over all the EU regions of the *RCES*, the *RC* and the *RES* indicators in 2008 and 2018, as well as for four groups of regions divided according to their location: North (which includes the regions of Denmark, Estonia, Finland, Ireland, Latvia, Lithuania and Sweden), South (Croatia, Cyprus, Greece, Italy, Malta, Portugal, Slovenia, and Spain), West (Austria, Belgium, France, Germany, Luxembourg, and the Netherlands), and East (Bulgaria, Czech Republic, Hungary, Poland, Romania, and Slovakia). The "% Change" column displays the change between 2008 and 2018.

Table 2. Values of the *RCS*, *RC*, and *RS* indicators in the regions of the EU27

Regions	*RCES*			*RC*			*RES*		
	2008	2018	% Change	2008	2018	% Change	2008	2018	% Change
EU	0.124	0.178	+44%	0.172	0.228	+33%	0.471	0.506	+7%
North	0.152	0.206	+36%	0.192	0.248	+29%	0.496	0.527	+6%
South	0.103	0.114	+11%	0.153	0.158	+3%	0.498	0.523	+5%
West	0.144	0.179	+24%	0.194	0.222	+14%	0.409	0.483	+18%
East	0.102	0.246	+141%	0.144	0.316	+119%	0.546	0.518	-5%

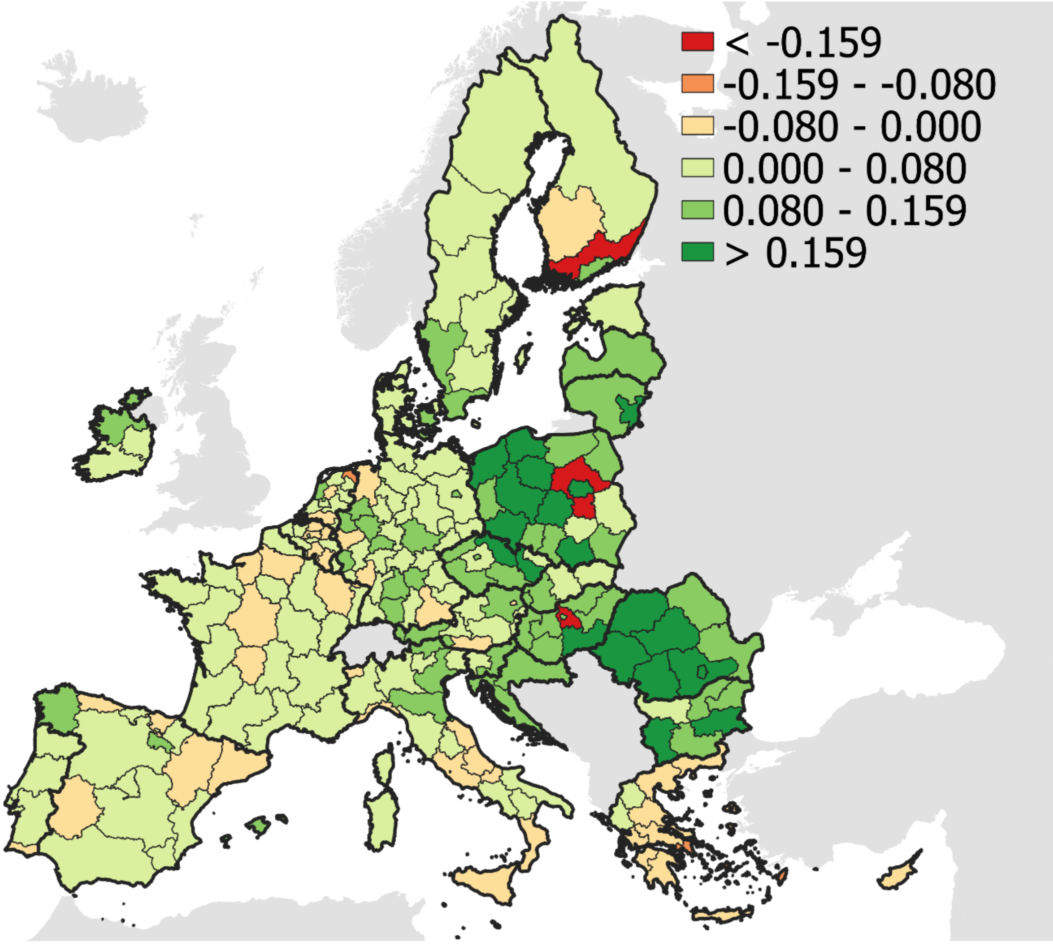
Source: own elaborations based on Eurostat and JRC-EDGAR data.

Note: RCES = Regional Competitive Environmental Sustainability indicator; RC = Regional Competitive indicator; RES = Regional Environmental Sustainability indicator.

The numbers in Table 2 should be read by keeping in mind that they refer to the regional positioning within each country, so they are not directly comparable across different countries or groups of them. The three indicators depict an interesting snapshot of the EU regions in terms of the sectoral composition of employment with respect to the competitive and environmental sustainable dimensions in 2008 and 2018. Overall, it appears that, in 2018, 17.8% of the employees of the EU regions on average were working in sectors which were at the same time more competitive and sustainable than their own country averages, representing an improvement of 44% with respect to 2008.

The value of the *RCES* indicator is the result of the overlapping between the 22.8% of employees working in sectors characterised by above-average productivity levels, and the 50.6% working in sectors with below-average air emissions intensity levels. The EU unweighted averages, though, mask considerable regional heterogeneity, with the Northern and Eastern and West regions being characterised by values of the indicators which are higher than the EU average. However, and inevitably, these average values of the indicators, although informative, are limited as to the extent of the information on the existing underlying regional heterogeneity. Figure 1 shows the mapping of the *RCES* changes in the EU regions between 2008 and 2018. Figure 2 and Figure 3 display the same information separately for the competitiveness (*RC*) and the environmental sustainability (*RES*) components of the indicator, respectively, again between 2008 and 2018.

Figure 1. 2008-2018 change of the *RCES* indicator at the NUTS 2 level, EU



Source: Own elaborations based on Eurostat and JRC-EDGAR data.

Note: RCES = Regional Competitive Environmental Sustainability indicator.

Figure 1 shows considerable within-country regional heterogeneity in terms of the 2008-2018 changes in the *RCES* values in most of the EU countries. The range of values is quite high, as the distribution lies between -23.9% and +62.3% (Table 3). There are only a few examples of countries in which most regions developed in a similar way over time, notably Romania and Bulgaria where all regions improved in terms of the *RCES* indicator.

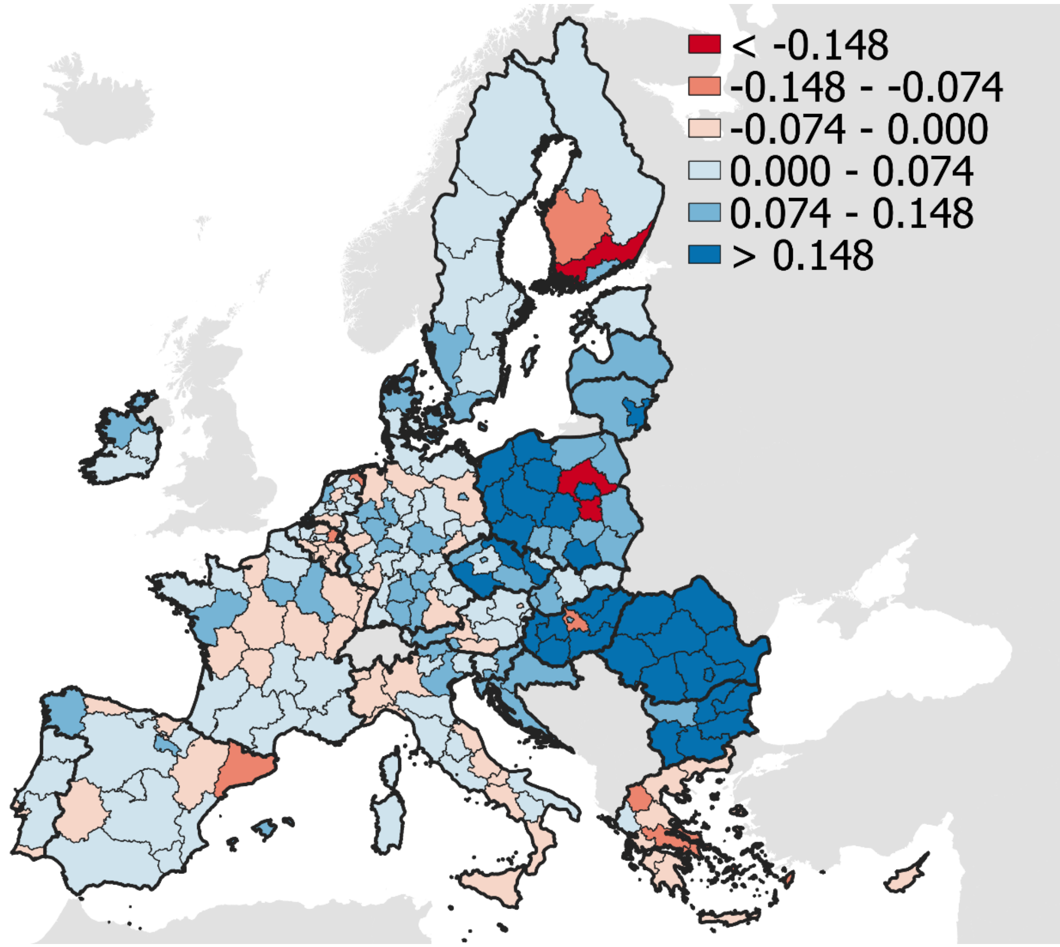
Table 3: Descriptive statistics of the difference in the RCS, RC and RS indicators between 2008 and 2018

Indicator	Mean	Std. dev.	Min	Max
RCES	0.054	0.088	-0.239	0.623
RC	0.056	0.100	-0.222	0.641
RES	0.034	0.108	-0.508	0.329

Source: own elaborations based on Eurostat and JRC-EDGAR data.

Note: 237 observations. Unit is change in percentage points. RCES = Regional Competitive Environmental Sustainability indicator; RC = Regional Competitive indicator; RES = Regional Environmental Sustainability indicator.

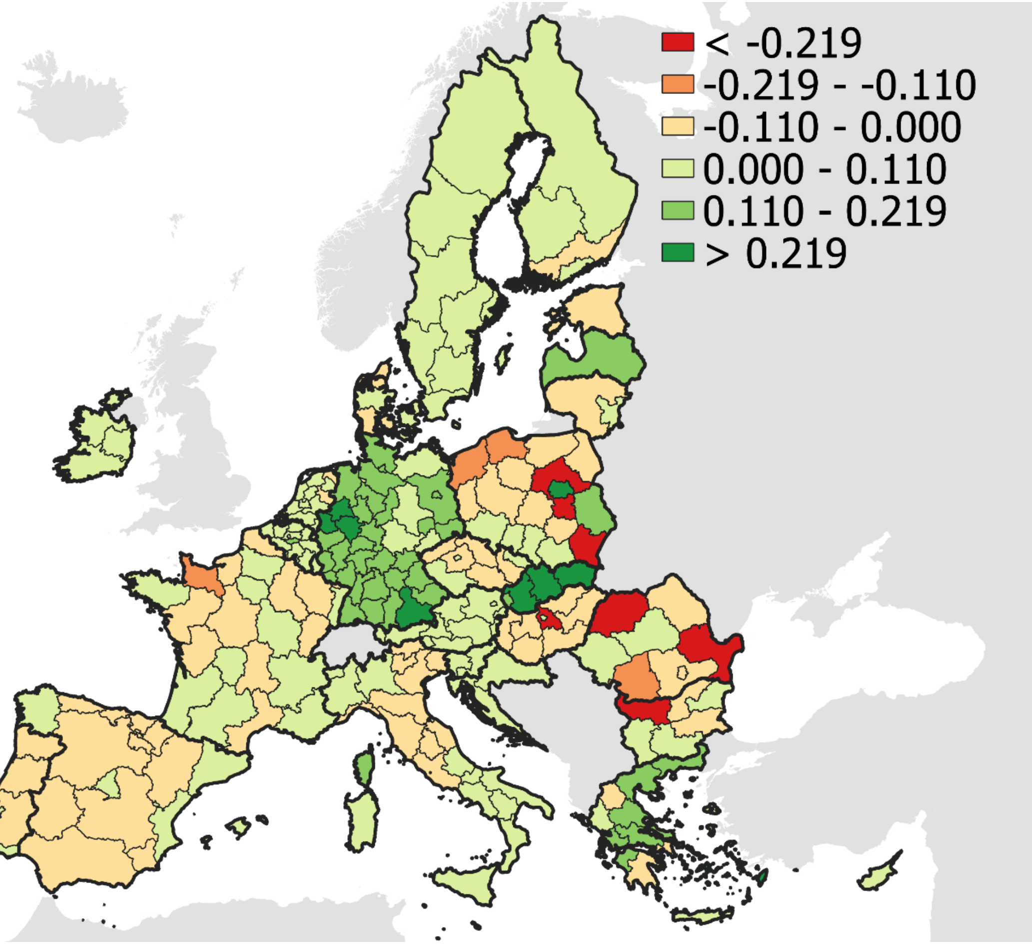
Figure 2. 2008-2018 change of the *RC* indicator at the NUTS 2 level, EU



Source: Own elaborations based on Eurostat and JRC-EDGAR data.

Note: RC = Regional Competitive indicator.

Figure 3. 2008-2018 change of the *RES* indicator at the NUTS 2 level, EU



Source: Own elaborations based on Eurostat and JRC-EDGAR data.
Note: RES = Regional Environmental Sustainability indicator.

According to Figures 2 and 3, the range of the 2008-2018 changes of the *RC* indicator is narrower than that of the changes of the *RES* indicator. Time variability is in both cases significant. For instance, German, Slovak and some Greek regions mostly improved over time in their green dimension (*RES* indicator - Figure 3), while in terms of competitiveness some regions of Romania, Bulgaria and Poland show impressive improvements (*RC* indicator - Figure 2). We turn to the next section in order to investigate econometrically what may drive these changes over time.

4. The European structural funds and the transition towards a more competitive and sustainable economy

4.1 Econometric model and data

To assess the potential effect of the European structural funds on the transition to a more competitive and environmental sustainable economy, we consider a fixed effects econometric model as expressed in equation (3) in which the dependent variable measures industrial transition. The dependent variable is expressed as the first difference of the log of *RCES*[6] ($\triangle \ln RCES_{i,t}$) to measure the change over time of the indicator introduced in equation (2).

$$\triangle lnRCES_{i,t} = \alpha + \beta lnRCES_{i,t-1} + \gamma lnFundPC_{i,t-1} + \delta X_{i,t} + \mu_i + \tau_t + u_{i,t} \quad (3)$$

The model includes as explanatory variables the lagged level of the *RCES* indicator in log ($lnRCES_{i,t-1}$), the lagged stock of EU structural funds per capita in log ($lnFundPC_{i,t-1}$), as well as a set of control variables related to regional macroeconomic conditions ($X_{i,t}$). The stocks of the EU structural funds are estimated using the Perpetual Inventory method (PIM) assuming a depreciation rate of 8%.[7] Data on EU funds payments at the NUTS 2 level refer to the European Regional Development Fund (ERDF), the European Social Fund (ESF), and the Cohesion Fund (CF), and come from the Cohesion data Portal.[8]

The EU Funds variable is lagged one period in order to account for potential reverse causality issues, as the funds may affect industrial transition, but at the same time they mostly target regions lagging behind in terms of competitiveness.

The additional control variables are the Quality of Government (*QoG*), the real growth of GDP per capita (constant price base 2005), the R&D stock[9] per capita, the share of employment with higher education, and employment density (persons employed per squared kilometer). The *QoG* indicator is extracted from the quality of government variable is taken from the European Quality of Government Index (Charron et al., 2021). The index is available only for 2010, 2013, 2017, and 2021. Following Rodríguez-Pose and Ketterer (2020), we build a time series by interpolating the middle

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[6] The dependent variable is not the log transformation of the *RCEST* reported in equation (2). Since *RCES* has negative values and taking logs would be problematic, we use the first difference of the log of *RCES*.

[7] Since the EU structural funds refer mainly to financial support for tangible investments, we consider a depreciation rate of 8%, usually used for physical capital stock (see e.g. Hall and Mairesse, 1995).

[8] https://cohesiondata.ec.europa.eu/ (accessed on 13 October 2021).

[9] Estimated using PIM and a depreciation rate of 15% following Hall and Mairesse (1995).

years. For the years before 2010, we assume that the regional quality of government difference with respect to the national quality of government is kept constant. For the national quality of government index, we use an unweighted average of the Control of Corruption (CC), Government Effectiveness (GE), Rule of Law (RL), and Voice and Accountability (VA) indicators of the Worldwide Governance Indicators. The data for all the remaining variables come from Eurostat. Table 4 below provides more detailed information on the model variables and the data sources.

Table 4. Model variables and data sources

Variables	Source	Description
RCES	Own estimation based on Eurostat and JRC-EDGAR data	Regional Competitive Environmental Sustainability Index
RC		Regional Competitive Index
RES		Regional Environmental Sustainability Index
Employment density	Own estimation based on Eurostat	Total persons employed per squared kilometer
Stock EU funds per capita	Own estimation based on Cohesion data Portal and Eurostat	Stock of EU funds payments (estimated using PIM and a depreciation rate of 8%) expressed per capita at constant price base 2005
GDP per capita	Eurostat	Gross domestic product per capita at constant price base 2005
Percentage High Education	Eurostat	Share of employment with higher education
Quality of Government	Charron et al. (2021)	European Quality of Government Index
R&D stock per capita	Own estimation based on Eurostat	Stock of Gross Expenditure on R&D (estimated using PIM and a depreciation rate of 15%) expressed per capita and at constant price base 2005

Source: Own elaboration.

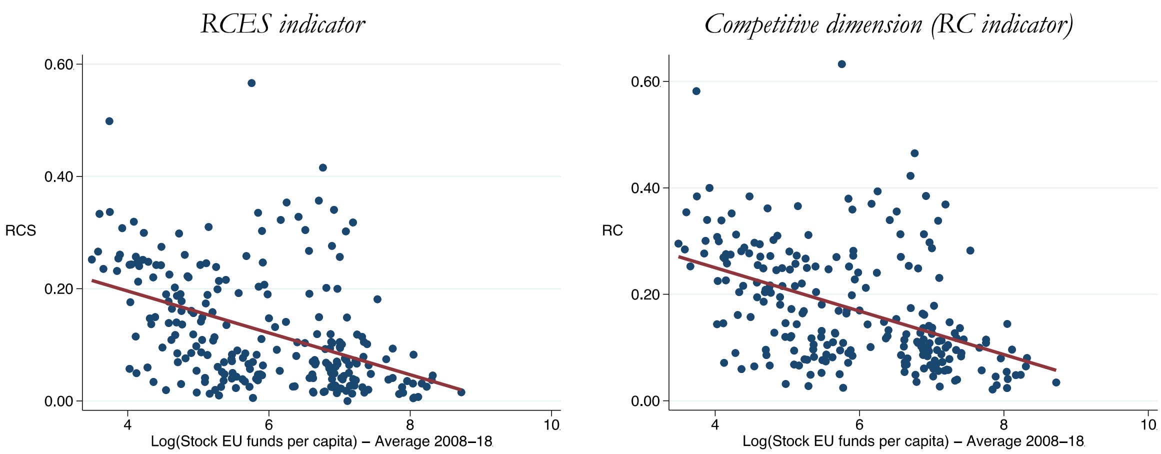
All the right-hand-side variables are identified in the scientific literature as determinants of the dynamics of employment across sectors, therefore we consider them as potential drivers of the transition performances as defined by the indicators we constructed (see e.g. Martins, 2019; Dabla-Norris et al., 2013). Finally, model (3) also includes fixed regional effects (μ_i) and annual time fixed effects (τ_t), and $u_{i,t}$ is the error term. We also present the results of model (3) estimated with either $RCT_{i,t}$ or $REST_{i,t}$ as alternative dependent variables in order to investigate the two components of the *RCES* indicator separately. Some descriptive statistics can be found in Table B1 in Appendix B.

4.2. Results and discussion

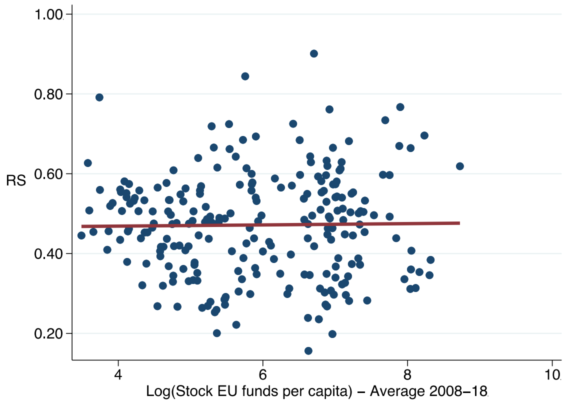
4.2.1. Understanding the geographical concentration of the EU structural funds

The EU structural funds mainly target the less developed regions of the EU with the objective of favouring convergence and cohesion. Thus, we expect the regions characterised by relatively lower values of the *RCES* indicator to be among the main beneficiaries of the funds. This intuition is confirmed by a simple correlation between the 2008 level of the three indicators presented above and the stock of EU Funds used in model (3) averaged over the 2008-2018 period, as shown by Figure 4. In particular, there is a negative and statistically significant correlation between the initial level of the *RCES* indicator and the amount of funds targeting the regions, driven by the competitive dimension (*RC*). The latter finding is demonstrated by the negative correlation with the *RC* indicator, and the lack of it with the *RES* indicator (see also Table B2 in Appendix B). This suggests that the policy is well designed as far as it is able to target the regions which are actually lagging behind in terms of economic performance (in this case measured by the share of employees in sectors with relatively high productivity within each country).

Figure 4. Two-way Scatterplots: RCS, RC and RS indicators (vertical axis) versus stock of EU funds per capita (in logs)



Environmental sustainable dimension (RES indicator)



Source: Own elaborations.

4.2.2. Assessing the effect of EU structural funds on industrial transition

Table 4 shows the estimated coefficients of three specifications of equation (3) using the fixed effects estimator, differing only for the dependent variable and the lagged level of the correspondent indicator. The coefficient associated with the lagged level of the indicator - from which the dependent variable is calculated as per equation (2) - is in all cases negative and statistically significant. This suggests that the lower (higher) the shares of employees in competitive and/or sustainable sectors in a region, the more probable it is for that region to experience an increase (a decline) in the value of the indicator. This is intuitive, as it would be easier to improve an initially relatively bad performance rather than a good one.

The coefficient of the log of the stock of EU structural funds per capita is positive and statistically significant for the *RCEST*[10] and *RCT* specifications (column (1) and (2) of Table 4), but negative for the *REST* one (column (3) of Table 4). These results suggest that the injection of EU funds is helping regions to restructure their employment towards more competitive and environmentally sustainable sectors within each country, with the first dimension dominating the second one, given the negative coefficient of column (3). One possible explanation for the latter results is that the EU structural funds mainly targeted the reduction of socio-economic inequalities and promoted economic cohesion rather than focusing on environmental sustainability.[11]

[10] For sensitivity purposes, we restimated the model in equation (3) removing the time dummies and/ some of the control variables. Table C2 in Appendix C shows that the estimated EU funds coefficient is stable across these different model specifications.

[11] Only a small percentage of the 2014-2020 ESIF budget was allocated to Thematic Objective 4 – Low Carbon Economy (Table C1 – Appendix C).

Table 4. Fixed Effects estimates, dependent variables: changes in the indicators as per equations (2) and (3) - $RCEST$ (1), RCT (2), and $REST$ (3)

Explanatory variables	$\triangle lnRCES_{i,t}$ (1)	$\triangle lnRC_{i,t}$ (2)	$\triangle lnRES_{i,t}$ (3)
Lag $RCES/RC/RES$ Indicator	-0.428***	-0.423***	-0.575***
	(0.039)	(0.040)	(0.033)
Log Stock EU funds per capita	0.227***	0.193***	-0.036**
	(0.036)	(0.028)	(0.014)
Quality of Government	0.118***	0.079***	0.031**
	(0.036)	(0.027)	(0.012)
Growth of GDP per capita	-0.108	0.140	0.354***
	(0.273)	(0.155)	(0.084)
Log R&D stock per capita	0.144*	0.103*	0.080*
	(0.078)	(0.061)	(0.045)
Log Percentage High Education	0.132	0.068	0.023
	(0.101)	(0.065)	(0.028)
Log Employment density	0.671**	0.536***	0.060
	(0.275)	(0.177)	(0.066)
Constant	0.765	0.422	0.539
	(1.039)	(0.768)	(0.430)
Year dummies	Yes	Yes	Yes
Observations	2,359	2,360	2,360
Regions	237	237	237
R^2	0.249	0.223	0.345
Wald test for joint significance	18.08	16.73	33.78

*Source: Own elaborations. Note: Cluster standard errors in parentheses. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Note that the dependent variable is calculated as* $ln(RCES_{i,t}) - ln(RCES_{i,t-1})$ *in order to interpret the coefficient of the EU funds variable as an elasticity. All the explanatory variables are in lag, except GDP per capita growth.*

The less developed regions of the EU (mainly in Eastern countries) are the ones receiving a higher amount of EU funds (see Table B4 in Appendix B), and they are the ones showing mostly positive improvements along the competitiveness dimension of our indicator (see Table 1). This suggests that, on the road to a competitive sustainability economy, less developed regions initially improve in terms of competitiveness, rather than environmental sustainability. This could also be interpreted as a trade-off between competitive and sustainability convergence for less developed regions during the initial phase of the transition, assuming that the less developed regions will eventually follow the same path as the currently more developed. Furthermore, transition towards a low-carbon economy requires more effort (not only related to socio-economic conditions, but also to the legal and institutional framework) than transition to a more competitive economy. Thus, any progress on the environmental side could take longer to materialise than mere economic and competitive improvements. It is also important to highlight that even if the performance of Eastern European regions in terms of environmental sustainable convergence is not as impressive as their competitiveness one, it does not mean that they are not using EU structural funds to promote low-carbon technologies[12]: it may simply mean that the effects are not visible in the period under analysis and according to the indicator used here.

As for the other control variables of the model, it appears that the coefficients of the Quality of Government and the R&D stock per capita are positive and statistically significant in all the model specifications, in line with previous literature findings on similar topics. For instance, Rodríguez-Pose and Ganau (2022) find that institutional quality positively influences regional productivity growth, both directly and indirectly through the short-run and long-run returns of innovation and human capital. However, our study is the first to link employment transitions towards more environmentally sustainable sectors to the quality of government. The link deserves further investigation as it confirms the intuitive expectation that regulation can play a key role. Also, employment density, used to capture agglomeration effects, appears to be positively associated to the changes in the *RCES* indicator, mainly driven by the competitiveness dimension (see the results for *RCT*). Previous studies (see e.g. Durantgon and Puga, 2004), already pointed out that agglomeration of firms and workers constitutes a source of knowledge generation, diffusion and accumulation. On the other hand, the growth of GDP per capita coefficient is only significant and positively associated with the environmental sustainable transition indicator, which may be due to the influence of changes in investment and demand conditions.

4.2.3. Assessing complementarities between EU funds and macro-economic conditions

We assess potential complementarities between the ERDF and the ESF by including them separately in the estimation of equation (3), and adding an interaction term between the two. Results show that the coefficients of the log of the stock of ERDF per capita and ESF per capita are positive and statistically significant for the *RCEST* and *RCT* specifications (columns (1) to (3) of Table 5 and Table 6), but negative for the *REST* one (columns (1) to (2) of Table 7). The addition of the interaction term between ERDF and ESF funds (columns (4) of Tables 5, 6 and 7) does not uncover any significant relationship between the two. Nevertheless, it seems that the ERDF is more related to the competitive transition than to the sustainable one.

[12] Marques Santos et al. (2022) showed that, for the period 2014-2020, central and eastern European regions are the ones with a higher share of low-carbon projects funded by the ERDF.

Table 5. Fixed Effects estimates, dependent variables: changes in the indicators as per equations (2) and (3), Y = $\triangle lnRCES_{i,t}$

Explanatory variables	(1)	(2)	(3)	(4)
Lag *RCES Indicator*	-0.436***	-0.415***	-0.435***	-0.436***
	(0.0394)	(0.0384)	(0.0398)	(0.0400)
Log Stock ERDF per capita	0.205***	-	0.146***	0.153***
	(0.0300)	-	(0.0393)	(0.0560)
Log Stock ESF per capita	-	0.175***	0.0784**	0.0878
	-	(0.0260)	(0.0329)	(0.0614)
Log Stock ERDF per capita # Log Stock ESF per capita	-	-	-	-0.00202
	-	-	-	(0.0111)
Year dummy and control variables	Yes	Yes	Yes	Yes
Constant	1.382	2.055**	1.325	1.340
	(0.944)	(0.989)	(0.958)	(0.977)
Observations	2,359	2,357	2,357	2,357
R-squared	0.251	0.244	0.254	0.254
Number of id	237	237	237	237

*Source: Own elaborations. Note: Cluster standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Note that the dependent variable is calculated as* $\ln(RCES_{i,t}) - \ln(RCES_{i,t-1})$ *in order to interpret the coefficient of the EU funds variable as an elasticity. All the explanatory variables are in lag, except GDP per capita growth.*

Table 6. Fixed Effects estimates, dependent variables: changes in the indicators as per equations (2) and (3), Y = $\triangle lnRC_{i,t}$

Explanatory variables	(1)	(2)	(3)	(4)
Lag *RC* Indicator	-0.429***	-0.402***	-0.430***	-0.430***
	(0.0401)	(0.0384)	(0.0401)	(0.0401)
Log Stock ERDF per capita	0.173***	-	0.135***	0.140***
	(0.0244)	-	(0.0353)	(0.0473)
Log Stock ESF per capita	-	0.140***	0.0506*	0.0580
	-	(0.0199)	(0.0285)	(0.0482)
Log Stock ERDF per capita # Log Stock ESF per capita	-	-	-	-0.00156
	-	-	-	(0.00844)
Year dummy and control variables	Yes	Yes	Yes	Yes
Constant	0.943	1.599**	0.922	0.933
	(0.678)	(0.709)	(0.687)	(0.696)
Observations	2,360	2,358	2,358	2,358
R-squared	0.225	0.213	0.227	0.227
Number of id	237	237	237	237

*Source: Own elaborations. Note: Cluster standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Note that the dependent variable is calculated as* $\ln(RC_{i,t}) - \ln(RC_{i,t-1})$ *in order to interpret the coefficient of the EU funds variable as an elasticity. All the explanatory variables are in lag, except GDP per capita growth.*

Table 7. Fixed Effects estimates, dependent variables: changes in the indicators as per equations (2) and (3), Y = $\triangle lnRES_{i,t}$

Explanatory variables	(1)	(2)	(3)	(4)
Lag *RES Indicator*	-0.573***	-0.578***	-0.579***	-0.578***
	(0.0339)	(0.0335)	(0.0330)	(0.0331)
Log Stock ERDF per capita	-0.0304**	-	-0.0126	-0.0277*
	(0.0122)	-	(0.0123)	(0.0167)
Log Stock ESF per capita	-	-0.0347***	-0.0259***	-0.0466**
	-	(0.0108)	(0.00982)	(0.0203)
Log Stock ERDF per capita # Log Stock	-	-	-	0.00443
ESF per capita	-	-	-	(0.00348)
Year dummy and control variables	Yes	Yes	Yes	Yes
Constant	0.417	0.402	0.475	0.442
	(0.392)	(0.364)	(0.392)	(0.394)
Observations	2,360	2,358	2,358	2,358
R-squared	0.345	0.347	0.348	0.349
Number of id	237	237	237	237

*Source: Own elaborations. Note: Cluster standard errors in parentheses. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Note that the dependent variable is calculated as* $\ln(RES_{i,t}) - \ln(RES_{i,t-1})$ *in order to interpret the coefficient of the EU funds variable as an elasticity. All the explanatory variables are in lag, except GDP per capita growth.*

Table 8 displays the results of the model estimated by adding an interaction term between EU funds and the share of employment with higher education, as well as, the stock of R&D. Results are particularly interesting for the sustainable transition indicator (columns (5) and (6) of Table 8), revealing a positive coefficient of EU funds in regions with higher-skilled labour and investing more in R&D. On the other hand, an inverse relationship is observed for the RCES indicator and the RC indicator (columns (1) to (4) of Table 78).

5. Conclusion

In this paper, we present a novel indicator of regional competitive sustainability based on the sectoral employment shares across all the regions of the EU. We show the mapping and the main statistical properties of the indicator accounting for competitiveness (in terms of productivity) and environmental sustainability (in terms of air emissions intensity), both when considered jointly and separately. There appears to be substantial regional heterogeneity in the EU for all the three versions of the indicator, as well as interesting dynamics over the 2008-2018 period.

The EU regions are faced with two big challenges for the next coming years: recovery from the Covid-19 crisis, and the transition to a climate neutral economy by 2050. Under the programming period 2021-2027, the EU has mobilised €750 billion to support the EU recovery, in addition to the

€1,074 billion of the EU's Multiannual Financial Framework (MFF). The results of our study can be particularly useful for policymakers to better understand what can enhance the transitions and the circumstances under which public support is proving effective.

Our findings show that the EU funds, which mostly target the less developed regions of the EU, are being deployed in regions characterised by relatively worse values of the competitiveness indicators, in line with the objectives of Cohesion policy. At the same time, our econometric analysis suggests that the funds do have a positive effect on the transition towards a competitive and environmentally sustainable economy, especially due to their influence on the competitiveness dimension. We also uncover a positive role played by both the quality of government and the stock of investments in R&D.

We believe that quantitative economic indicators of the type we propose here could be used in the context of policy making besides being useful for in-depth economic analyses such as ours. For instance, these indicators could be used as targets for the regions in the process of transitioning to a competitive and sustainable economy by setting a minimum share of employment in high productivity and low emission sectors that regions must achieve.

Table 8. Fixed Effects estimates, dependent variables: changes in the indicators as per equations (2) and (3): RCEST, RCT and REST,

	$\triangle lnRCES_{i,t}$		$\triangle lnRC_{i,t}$		$\triangle lnRES_{i,t}$	
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Lag *RCES* / *RC* / *RES* Indicator	-0.443***	-0.458***	-0.438***	-0.449***	-0.575***	-0.581***
	(0.0359)	(0.0409)	(0.0384)	(0.0400)	(0.0330)	(0.0320)
Log Stock EU funds per capita	0.000467	-0.586***	0.0183	-0.381***	0.00540	0.0755
	(0.0765)	(0.128)	(0.0548)	(0.0904)	(0.0192)	(0.0577)
Log Percentage High Education	1.077***	0.136	0.794***	0.0691	-0.147	0.0228
	(0.284)	(0.102)	(0.218)	(0.0633)	(0.0985)	(0.0296)
Log R&D stock per capita	0.195**	0.725***	0.141**	0.512***	0.0719*	0.00331
	(0.0765)	(0.112)	(0.0571)	(0.0704)	(0.0427)	(0.0518)
Log Stock EU funds per capita # Log Percentage High Education	-0.156***	-	-0.120***	-	0.0280*	-
	(0.0497)	-	(0.0371)	-	(0.0159)	-
Log Stock EU funds per capita # Log R&D stock per capita	-	-0.0994***	-	-0.0701***	-	0.0135*
	-	(0.0156)	-	(0.0113)	-	(0.00787)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.205**	6.039***	1.521**	4.125***	0.286	-0.163
	(1.039)	(1.389)	(0.733)	(0.901)	(0.376)	(0.431)
Observations	2,359	2,359	2,360	2,360	2,360	2,360
R-squared	0.257	0.270	0.231	0.242	0.347	0.349
Number of id	237	237	237	237	237	237

Source: Own elaborations.

*Note: Cluster standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Note that the dependent variable is calculated as* $\ln(RES_{i,t}) - \ln(RES_{i,t-1})$ *in order to interpret the coefficient of the EU funds variable as an elasticity. All the explanatory variables are in lag, except GDP per capita growth.*

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Appendix

Appendix A. NACE activities in the RCES indicator

Table A1. List of NACE activities included in the Regional Competitive Environmental Sustainability (*RCES*) indicator

NACE code	NACE description
A	Agriculture, forestry and fishing
B	Mining and quarrying
C10	Manufacture of food products
C11	Manufacture of beverages
C13	Manufacture of textiles
C14	Manufacture of wearing apparel
C15	Manufacture of leather and related products
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17	Manufacture of paper and paper products
C18	Printing and reproduction of recorded media
C19	Manufacture of coke and refined petroleum products
C20	Manufacture of chemicals and chemical products
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22	Manufacture of rubber and plastic products
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacture of computer, electronic and optical products
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment n.e.c.
C29	Manufacture of motor vehicles, trailers and semi-trailers
C30	Manufacture of other transport equipment
C31	Manufacture of furniture
C32	Other manufacturing
C33	Repair and installation of machinery and equipment
D	Electricity, gas, steam and air conditioning supply
E	Water supply; sewerage, waste management and remediation activities
F	Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
H49 + H53	Land transport and transport via pipelines (H49) + Postal and courier activities (H53)
H50	Water transport
H51	Air transport

Continued in the next page…

Table A1. List of NACE activities included in the Regional Competitive Environmental Sustainability (*RCES*) indicator (continuation)

NACE code	**NACE description**
H52	Warehousing and support activities for transportation
I55	Accommodation
I56	Food and beverage service activities
J58	Publishing activities
J59	Motion picture, video and television programme production, sound recording and music publishing activities
J60	Programming and broadcasting activities
J61	Telecommunications
J62	Computer programming, consultancy and related activities
J63	Information service activities
L	Real estate activities
M69	Legal and accounting activities
M70	Activities of head offices; management consultancy activities
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development
M73	Advertising and market research
M74	Other professional, scientific and technical activities
M75	Veterinary activities
N77	Rental and leasing activities
N78	Employment activities
N79	Travel agency, tour operator and other reservation service and related activities
N80	Security and investigation activities
N81	Services to buildings and landscape activities
N82	Office administrative, office support and other business support activities
S	Other services

Source: Own elaboration.

Appendix B. Descriptive statistics and collinearity diagnostic

Table B1. Descriptive Statistics, Panel Data

Variables	Mean	Std. Dev.	Min	Max
RCES	0.14	0.11	0.00	0.90
RC	0.19	0.11	0.01	0.95
RES	0.49	0.12	0.11	1.06
Stock EU funds per capita	739.3	913.6	9.8	7,033.5
Quality of Government	0.12	0.98	-2.80	2.82
Growth of GDP per capita	0.01	0.04	-0.16	0.54
R&D stock per capita	0.00	0.00	0.00	0.01
% Empl. with higher education	0.30	0.09	0.10	0.61
Employment density	0.13	0.29	0.00	2.85

Source: Own elaborations. Note: 2,359 observations.

Table B2. Pairwise correlation coefficients between the RCES, RC and RES indicators in 2008 and the stock of EU funds per employee (in logs) averaged over 2008-2018

#	Variables		Correlation Matrix			
			1	2	3	4
1	Log(Stock EU funds per capita) - Average 2008-18		1			
2	Share employment High Prod and Low Emissions (RCES) - 2008	Coeff.	-0.4431	1		
		P-value	0.000			
3	Share employment High Prod (RC) - 2008	Coeff.	-0.4571	0.9617	1	
		P-value	0.000	0.000		
4	Share employment low emission (RES) - 2008	Coeff.	0.0142	0.4010	0.3310	1
		P-value	0.8274	0.000	0.000	

Source: Own elaborations.

Table B3. Variance inflation factors (VIF) and correlation matrix, Panel data

#	Variable	VIF	1	2	3	4	5	6	7
1	RCES	1.49	1						
2	Stock EU funds per capita	1.29	-0.37	1					
3	Quality of Government	1.59	0.26	-0.35	1				
4	Growth of GDP per capita	1.03	0.13	-0.04	-0.01	1			
5	R&D stock per capita	1.94	0.47	-0.39	0.57	0.01	1		
6	% Empl. with higher education	1.33	0.34	-0.18	0.32	0.10	0.42	1	
7	Employment density	1.21	0.33	-0.15	0.07	0.00	0.27	0.30	1
	Mean VIF	1.41							

Source: Own elaborations.

Table B4: GDP per capita in 2008 and Stock of EU Funds per capita in 2018

Regions	**GDP per capita 2008 (Euros)**	**Stock EU Funds per capita 2018 (Euros)**
EU	22,574.35	794.71
North	31,411.41	432.40
South	20,813.55	1,362.02
West	29,191.73	276.26
East	7,866.13	1,246.47

Source: Own elaboration based on Eurostat data.

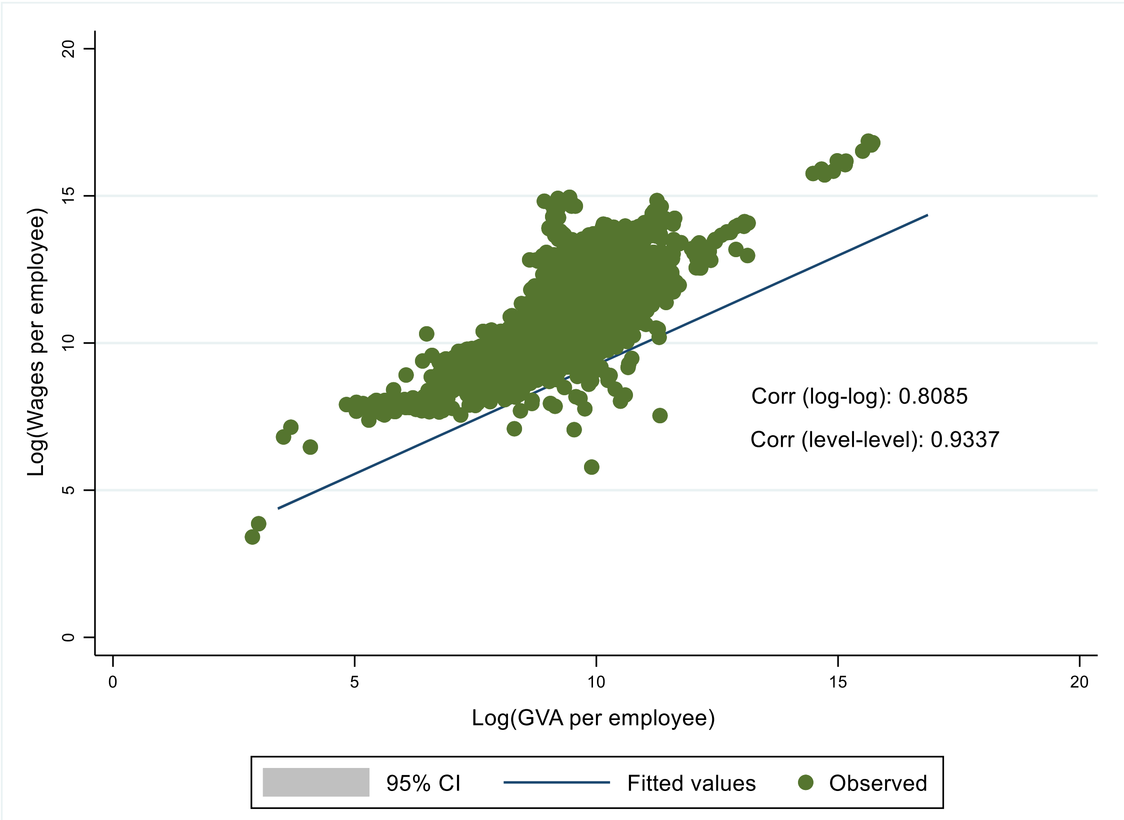
Appendix C. Sensitive and Complementarity Analysis

Table C1. ESIF 2014-2020: Total budget by Thematic Objective, EUR Million

Thematic Objective		Funds					TOTAL	
		CF	EAFRD	EMFF	ERDF	ESF	EUR	% Total
1	Research & Innovation	0	2,663	0	41,104	0	43,767	8%
2	Information & Communication Technology	0	994	0	11,722	0	12,716	2%
3	Competitiveness of SMEs	0	39,801	2,893	40,920	0	83,615	16%
4	**Low-Carbon Economy**	**7,800**	**5,446**	**53**	**29,076**	**0**	**42,375**	**8%**
5	Climate change adaptation & Risk prevention	3,567	29,416	0	3,689	0	36,672	7%
6	Environmental Protection & Resource efficiency	15,667	35,010	1,845	18,330	0	70,852	13%
7	Network infrastructure in Transport and Energy	32,287	0	0	23,542	0	55,829	11%
8	Sustainable & Quality Employment	0	2,892	590	3,414	28,134	35,030	7%
9	Social Inclusion	0	15,005	0	13,970	23,435	52,411	10%
10	Educational & Vocational Training	0	1,049	0	6,971	25,924	33,944	6%
11	Efficient Public Administration	0	0	0	1,304	3,429	4,732	1%
	Technical Assistance	2,134	2,986	269	5,984	3,979	15,352	3%
	Other	0	481	0	26,083	14,898	41,462	8%
	TOTAL	61,455	135,745	5,651	226,108	99,798	528,757	100%

Source: Open Cohesion Data.

Figure C1. Two-way Scatterplots: Wages per employee (vertical axis) versus GVA per employee (in logs)



Source : Own elaboration based on Eurostat data.

Note: values refers to country-industry indicator observations over the period 2008-2018 in the EU27. Number of observations: 23,542.

Table C2. Fixed Effects estimates, dependent variables: changes in the indicators as per equations (2) and (3) – $RCEST$ (sensitivity analysis)

Explanatory variables	(1)	(2)	(3)	(4)
Lag *RCES* indicator	-0.375***	-0.385***	-0.394***	-0.406***
	(0.0356)	(0.0386)	(0.0396)	(0.0375)
Log Stock EU funds per capita	0.235***	0.244***	0.207***	0.244***
	(0.0337)	(0.0335)	(0.0351)	(0.0322)
Quality of Government	-	-	-	0.143***
	-	-	-	(0.0363)
Growth of GDP per capita	-	-	-	-0.348
	-	-	-	(0.273)
Log R&D stock per capita	-	-	0.229***	-
	-	-	(0.0749)	-
Log Percentage High Education	-	-	-	0.102
	-	-	-	(0.0994)
Constant	-2.204***	-2.320***	-0.519	-2.263***
	(0.258)	(0.261)	(0.634)	(0.273)
Year dummy	No	Yes	Yes	Yes
Observations	2,369	2,369	2,369	2,359
R-squared	0.189	0.221	0.226	0.237
Number of id	237	237	237	237

Source: Own elaborations.

*Note: Cluster standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Note that the dependent variable is calculated as* $\ln(RCES_{i,t}) - \ln(RCES_{i,t-1})$ *in order to interpret the coefficient of the EU funds variable as an elasticity. All the explanatory variables are in lag, except GDP per capita growth.*

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