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Resource Productivity and Eco-Innovation Convergence in the Service of Sustainability. Evidence from the EU-28

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Abstract
The European Green Deal prioritizes green growth through resource efficiency and eco-innovation to achieve the transition in a sustainable and inclusive growth orbit. To monitor progress in such endeavor the EU Resource Efficiency Scoreboard was launched. Focusing on the resource productivity, which is the main sustainability development indicator and policy evaluation tool for Europe and the eco-innovation performance of the EU-28 over a twenty-year period, from 2000 though 2019, we explore convergence patterns and club formation. Descriptive analysis via growth rates of the resource productivity and eco-innovation indicates productivity differentials among the countries giving rise to heterogeneity groups. Econometric results using convergence algorithms advocate in favor of convergence for both variables. However, convergence clubs surface highlighting that there is heterogeneity to consider when designing policies to promote sustainability transition to ensure that no one is left behind serving the priority of inclusive and sustainable growth.

Keywords: Resource Productivity, Eco-Innovation, Sustainability, Convergence, Technological Heterogeneity, European Green Deal

1. Introduction and Motivation

Over the years the European Union has built a coherent framework to facilitate sustainable and inclusive growth through resource efficiency starting from the Thematic Strategy on the sustainable use of natural resources (European Commission, COM/2005/670). The target was to mitigate the environmental degradation occurring as the result of scarce resources utilization aspiring to achieve sustainable development. Resource efficiency holds a distinctive place among the priorities of the strategy. Practically, resource efficiency is about using scarce resources in a sustainable manner given technology level. Resource efficiency was further strengthened by the launch of the Europe 2020 Strategy (European Commission, COM/2010/2020), a strategy focusing on smart growth, enhancing competitiveness, resource utilization, innovation, the knowledge base of the European countries and social cohesion among other, for the decade to come.

Such being the case, one of the top priorities of the Europe 2020 Strategy is the Resource Efficiency Flagship Initiative (European Commission, COM/2011/0571 - b) materialized via the Roadmap to a Resource Efficient Europe outlining how to *support sustainable growth through resource efficiency and economy decarbonization by 2050* while later the same year the Eco-Innovation Action Plan was launched and adopted (European Commission, COM/2011/0899 – a) with the aim to support eco-innovation i.e., innovations towards sustainable growth and positive environmental effects and boost resource efficiency. Those strategies and directives have been endorsed by the European Green Deal, the new growth strategy of Europe (European Commission, COM/2019/640).

To monitor the progress of the European countries on resource efficiency aspects, the EU Resource Efficiency Scoreboard was introduced. The latter includes a three-tier system consisting of the lead indicator, which is resource productivity, the dashboard indicators as well as several thematic indicators. Resource productivity is considered as a sustainability indicator for the EU and is used as a policy evaluation tool. Moreover, the Scoreboard also monitors eco-innovation performance through the Eco-Innovation index. Such data provide the ground for fruitful discussion and reflections on tracing the sustainability transition of European countries, however, studies have not been surfaced yet to employ such valuable information even though recent evidence indicates that heterogeneous levels of environmental awareness exist as well as sustainability discrepancies among the EU-28 (Chatzistamoulou and Koundouri, 2022; 2021).

Such being the case, by employing information provided by the Scoreboard, *we focus on resource productivity and eco-innovation as integral parts of the sustainability transition to investigate whether there are convergence patterns that form clubs of similar performance among the EU-28 for the last twenty years.* Evidence indicates that convergence clubs emerge for both indicators giving rise distinct groups offering opportunity for tailored made measures to foster sustainability transition. Overall, European countries' performance in sustainability and eco-innovation appears to show signs of convergence which is particularly promising in the pursue of sustainability transition. In what follows we present the data, the method used to explore convergence, the discussion of the results and some concluding remarks.

2. Data and methods

2.1 Data

We devide a balanced panel covering the EU-28[1] for a twenty-year period, from 2000 through 2019. Thus, there are 560 observations in the panel dimension. We collect data on the resource productivity and eco-innovation index from Eurostat (2022). Those are part of the EU Resource Efficiency Scoreboard, a 3-tier system based on a lead indicator, a dashboard of indicators focusing on resource management and environmental impact and a set of thematic indicators monitoring policy effectiveness.

Resource productivity is the lead indicator defined as the ratio of the gross domestic product (GDP) to the domestic material consumption (DMC) measuring the amount of GDP generated per unit of direct material consumed, i.e., euros/kg (Eurostat, 2022). It is the European Union's sustainable development indicator for policy evaluation providing insights into whether decoupling between the use of natural resources and economic growth occurs. Recent findings indicate resource productivity could positively influence sustainability transition across the EU-28 (Chatzistamoulou and Tyllianakis, 2022).

Eco-Innovation[2] is a thematic indicator published by the Eco-Innovation Observatory in 2010 for the first time. It is a multi-faceted index appropriate for benchmarking (Park et al., 2017), comprised by five thematic areas[3] including 16 sub-indicators from eight contributors monitoring eco-innovation of the member states. It is part of a holistic approach in measuring the innovativeness of the EU member states (Eurostat, 2022). Evidence from the EU-28 indicates that eco-innovation could boost green growth and sustainability transition, especially in member states with performance at the sustainable development goals index lower than the European average (Chatzistamoulou and Tyllianakis, 2022).

2.2 Method: Convergence analysis and club formation

To investigate whether there are distinct clubs within the EU-28, we proceed with convergence analysis. *We test whether convergence clubs co-exist based on the resource productivity and eco-innovation performance[4], as integral parts of the sustainability transition,* by employing the method of Phillips and Sul (2007). Technical details rcan be found in Camarero et al. (2013) and Du (2017).

3. Results & Discussion

Figure 1 below illustrates the average growth rates of resource productivity and eco-innovation performance of the EU-28. Evidence indicates there are countries exhibiting similarities in their growth rates that could lead in the formation of groups of countries.

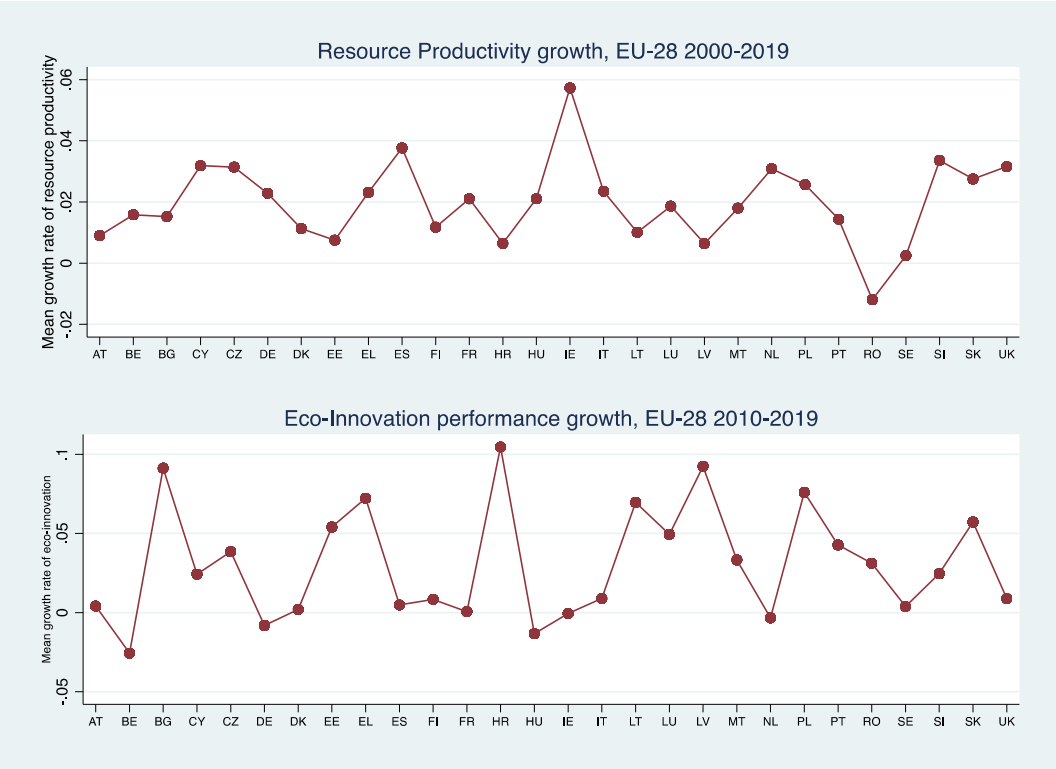
[1] Austria (AT), Belgium (BE), Bulgaria (BG), Croatia (HR), Cyprus (CY), Czech Rep. (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (EL), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithouania (LT), Luxembourg (LU), Malta (MT), Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Slovak Rep. (SK), Slovenia (SL), Spain (ES), Sweden (SE), United Kingdom (UK). The UK has been included as during period covered was subject to the European policy reporting data on the selected variables.

[2] Eco-Innovation launched in 2010.

[3] Eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency outcomes and socio-economic outcomes.

[4] Estimations for both variables include the UK.

Figure 1. Average growth rates of resource productivity and eco-innovation, EU-28.



Source: Authors' construction.

The first panel of Table 1 identifies five convergence clubs, by testing whether resource productivity levels converge. Resource productivity levels of countries in Clubs 1 to 4 appear to be convergent, except for Club 5, where there is not strong evidence to reject the null. The latter finding echoes findings of other studies showcasing discrepancies in the sustainable development goals index in the EU-28 (Chatzistamoulou and Koundouri, 2021).

The second panel explores possible club merging, by testing whether individual clubs could be merged to form a larger convergent club. Results indicate that the only clubs that could form a larger club are clubs 2 and 3 (Clubs 2+3). The last panel of Table 1 summarizes the final convergence clubs, highlighting that there is heterogeneity to consider when designing policies to promote sustainability.

Table 1. Resource productivity convergence clubs, EU-28.

H_0: *Resource Productivity convergence*					
log(t)	**Club1**	**Club2**	**Club3**	**Club4**	**Club5**
Coeff **(Std Error)**	-.139 (.152)	.131 (.229)	.161 (.241)	-.170 (.938)	1.244 (.724)
t-stat	-.909	.571	.668	-.181	1.718
Countries	BE, DE, ES, FR, IE, IT, LU, NL, UK	AT, CY,DK, EL, MT, SE, SL, SK	CZ, FI, HR, LV, PT	HU, LT, PL	BG, RO

H_0: Club Merging				
log(t)	**Club1+2**	**Club2+3**	**Club3+4**	**Club4+5**
Coeff (Std Error)	-.694 (.083)	-.189 (.203)	-.737 (.084)	-.977 (.212)
t-stat	-8.371	-.930	-8.832	-4.598
Final Resource Productivity clubs				
log(t)	**Club1**	**Club2**	**Club3**	**Club4**
Coeff	-.139	-.189	-.17	1.244
t-stat	-.909	-.93	-.181	1.718
Countries	BE, DE, ES, FR, IE, IT, LU, NL, UK	AT, CY, CZ, DK, EL, FI, HR, LV, MT, PT, SE, SL, SK	HU, LT, PL	BG, RO

Notes: (i) T-stat is compared to -1.65 critical value to decide whether to reject the null hypothesis at 5% level of significance, (ii) stars indicate statistical significance or that the null is rejected, (iii) the first 4 periods are discarded before regression, (iv) EE is non-convergent.

Table 2 below identifies convergence clubs based on the eco-innovation performance. The first panel of Table 2 provides strong evidence that the null hypothesis of convergence is not rejected. Thus, eco-innovation performance converges forming 5 clubs, however the second panel indicates there is not significant evidence to support further club merging. The last panel of Table 2 showcases the final club formation, where Clubs 3 and 4 could form a larger club, whereas the rest of the club participation remains unchanged. Based on the eco-innovation performance and club formation, sustainability transition could be fostered by boosting any of the thematic areas and indicators included in the eco-innovation index, particularly in the countries of lower performance.

Concluding, European countries exhibit club convergence both in terms of resource productivity and eco-innovation performance. Club formation could be grounded on resource endowment, competitiveness, technological opportunities, and institutions leading to insufficient resource allocation (Amankwah-Amoah et al., 2021). Technological heterogeneity and absorptive capacity have been acknowledged as factors provoking productivity differentials in the EU as well as globally (Chatzistamoulou et al., 2019; Tsekouras 2016; 2017).

Table 2. Eco-Innovation convergence clubs, EU-28.

H_0: *Eco-Innovation performance convergence*					
log(t)	**Club1**	**Club2**	**Club3**	**Club4**	**Club5**
Coeff (Std Error)	-.952 (.853)	-.897 (.659)	.064 (.144)	.092 (.334)	-.424 (.284)
t-stat	-1.116	-1.362	.443	.274	-1.497
Countries	DK, FI, LU	AT, SE	DE, IT, LT, UK	CZ, EL, ES, FR,	BE, BG, CY, ES,

				IE, LV, NL, PT, SL, SK	HU, MT, PL, RO
H_0: Club Merging					
log(t)	**Club1+2**	**Club2+3**	**Club3+4**	**Club4+5**	
Coeff (Std Error)	-.911 (.220)	-.216 (.111)	-.110 (.194)	-.709 (.217)	
t-stat	-4.135	-1.949	-.569	-3.270	
Final Eco-Innovation clubs					
log(t)	**Club1**	**Club2**	**Club3**	**Club4**	
Coeff	-.952	-.897	-.11	-.424	
T-stat	-1.116	-1.362	-.569	-1.497	
Countries	DK, FI, LU	AT, SE	DE, IT, LT, UK, CZ, EL, ES, FR, IE, LV, NL, PT, SL, SK	BE, BG, CY, ES, HU, MT, PL, RO	

Notes: (i) T-stat is compared to -1.65 critical value to decide whether to reject the null hypothesis, (ii) stars indicate statistical significance or that the null is rejected, (iii) the first 2 periods are discarded before regression, (iv) Croatia is not included in the analysis as data was inconsistent before 2013, when it became part of the EU.

4. Concluding remarks

The European Union supports sustainability transition and inclusive growth through several policy directives. To monitor progress towards sustainable growth, the EU Resource Efficiency Scoreboard was launched. Focusing on resource productivity and eco-innovation performance, we conduct convergence analysis to explore whether convergence clubs are formed to find that convergence clubs, both for the resource productivity as well as the eco-innovation, are formed within the EU-28 for the period considered. This indicates that despite the sustainability discrepancies, European countries exhibit patterns of convergent behavior indicating that those are on a track to achieve sustainable growth. Future policies should further facilitate catch-up to ensure that no one is left behind serving the priority of inclusive and sustainable growth.

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