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"UN-SUSTAINABLE" DEVELOPMENT GOALS AS A NEW DIMENSION OF THE EMU CORE-PERIPHERY DUALISM

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"Un-sustainable" development goals as a new dimension of the EMU Core-Periphery dualism

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Abstract

Despite widespread recognition of the importance of the issue, economic literature to the best of our knowledge has neglected the role of the Sustainable Development Goals (SDGs) in the persistent core periphery dualism in European Monetary Union (EMU). This gap is peculiar since starting from 2015 (and even before with the Millennium goals and the OECD DAC International Development Goals) the European Union (EU) has shaped its economic policies in order to reach the 17 SDGs by 2030.

In this paper we intend to fill this gap. We contribute to the empirical literature in two ways i) assessing whether the SDGs might represent themselves a new dimension of EMU core periphery dualism and ii) whether the similarity of SDGs scores for EMU country pairs have been affecting the existing dualism.

The cluster analysis performed evidenced that there was a Core-Periphery pattern for SDGs scores in the period 2001-2021 for 12 EMU countries, although the distance between and within the two groups diminished overtime. Moreover, panel estimates for the period 2003-2019 evidenced that there was a relationship between SDGs scores similarity and business cycle synchronization for the selected EMU countries.

According to our estimates, it seems that having a similar pattern to reach the SDGs displayed a differentiated impact on core and periphery countries. Moreover, disentangling the SDGs similarity index in its three main components (the 3Ps) evidenced heterogeneous and even opposite relationships with business cycle correlation.

JEL CODE: C5, E3, N1, F4, Q01

KEYWORDS: Euro, Core-Periphery, Convergence, Sustainable development

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Introduction

The European Union (EU) played a key role in the design and adoption of the Agenda 2030 for sustainable development[1] and has been particularly active in including the 17 Sustainable Development Goals (SDGs) in various policies for member countries since 2015 (Borchardt S. et al 2023). It is worth noticing that, previously, since their adoption in 2000, the EU has been also committed to the Millennium Development Goals and (since 1996) the OECD DAC International Development Goals[2], progressively adapting its economic policy to achieve them.

The process to meet the 17 ambitious goals within 2030 involves EU countries singularly as well as a group, including as a matter of fact European Monetary Union (EMU) aggregate.

Despite widespread recognition of the importance of the issue, the relevant literature to the best of our knowledge, has neglected the effect of the UN Agenda 2030 (i.e. the process to reach the 17 SDGs) on the core periphery (C-P) dualism among EMU members.

This gap in the literature is unfitting since the EU and its Member States are strongly committed to the 2030 Agenda, as outlined in the Communication "Next steps for a sustainable European future" (EC, 2016), which included the SDGs integration into the European policy framework and Commission priorities[3].

There are few empirical papers assessing whether there is a relationship between the Core-Periphery dualism in the EMU and social and economic indicators included in the SDGs such as income inequality, institutional quality or migration flows (Cesaroni, D'Elia and De Santis 2019, Esposito, Collignon and Scicchitano 2020).

Notably, a paper by Bacchini, Cannata and Donà (2020) using the Macroeconomic Imbalance procedure scoreboard[4], thus considering social development indicators also included in the SDGs, evidenced that the economic and financial crises have reinforced divergence across EMU countries, underlining the presence of a core and a periphery subset of countries.

In fact, the progress towards the SDGs at differentiated speed might be shaping itself as a core periphery pattern and the heterogeneous redistributive impacts of the process to reach the 17 goals on the single EMU countries might even have accentuated (or reduced) the pre-existing dualism. To the best of our knowledge, there are not empirical researches investigating whether the C-P dualism is somehow related to the SDGs or if the latter themselves can be considered a new dimension of the dualism.

It is worth to recall that the core periphery dualism was initially acknowledged by Bayoumi and Eichengreen (1997), who evidenced this pattern in the process towards the creation of EMU[5]. In the framework of the optimal currency area theory, they identified demand and supply shocks

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[1] The Agenda is a plan of action for people, planet and prosperity. It also seeks to strengthen universal peace in larger freedom. It was approved with a United Nations General Assembly resolution on the 25th of September 2015, adopted by 193 countries. It includes 17 Sustainable Development Goals and 169 targets. Goals are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental. The Goals and targets will stimulate action in areas of critical importance for humanity and the planet. On 6 July 2017, the SDGs were made more "actionable" by a UNGA resolution that identifies specific targets for each goal and provides indicators to measure progress. Most targets are to be achieved by 2030, although some have no end date.

[2] The Millennium Development Goals (MDGs) were eight international development goals set by UN in 2000 for the year 2015, following the adoption of the United Nations Millennium Declaration. These were based on the OECD DAC International Development Goals agreed by Development Ministers in the "Shaping the 21st Century Strategy". The SDGs succeeded the MDGs in 2016.

[3] Sustainability is also a core principle in the current Commission and the 2019-2024 strategic agenda sets the achievement of the 2030 Agenda as one of its main objectives (EC, 2019).

[4] The MIP scoreboard includes fourteen headline indicators for the identification and monitoring of external and internal macroeconomic imbalances as well as employment and social developments in order to gain a broader understanding of the social consequences of macroeconomic imbalance.

5 On the contrary, Frankel and Rose, 1998 according to the endogenous view of optimum currency area theories stated that the positive link between income correlation and trade integration is magnified for countries joining a currency union, and therefore the conditions for an OCA might be satisfied ex post even if they were not met ex ante. This generated the heated debate with advocates of trade "specialisation" (Krugman and Venables, 1995)

using long-run restrictions in a structural framework (Blanchard and Quah 1989). They found a core where supply-side shocks were highly correlated (Germany, France, Belgium, Netherlands, and Denmark) and a periphery where shocks were uncorrelated (Greece, Ireland, Portugal, Spain, Italy, and the UK). They suggested that if persistent, this countries polarization would have been detrimental to the well-functioning of EMU especially because of the one fits all monetary policy and the bounded fiscal policies.

The Bayoumi and Eichengreen seminal paper has been generating in the past three decades an intense debate among economists about causes and consequences of the core periphery dualism (De Grauwe, 2018) [6]. There have been many attempts to identify precisely the two groups of countries also using dynamic approaches to investigate the behavior of core and periphery groups over time (Campos and Macchiarelli 2021). Many papers empirically identified the presence of a dualism for the EMU countries which has been persistent over time (e.g. Caporale et al. 2014, Cesaroni and De Santis 2016; Esposito 2017; Esposito and Messori, 2018; Adarov, 2021).

This paper contributes to the existing literature in two ways: i) assessing whether the SDGs might represent themselves a new dimension of the EMU core periphery dualism and ii) whether the similarity of SDGs scores for 12 EMU country pairs have been affecting the existing dualism.

The cluster analysis performed evidenced that there was a Core-Periphery pattern for SDGs scores in the period 2001-2021 for 12 EMU countries although the distance between and within the two groups diminished overtime. Moreover, panel estimates for the period 2003-2019 evidenced that there was a relationship between SDGs scores similarity and business cycle synchronization for the selected EMU countries. According to our estimates, being on a similar pattern to meet Agenda 2030 targets is associated with business cycle greater correlation among core countries but not among peripheral ones.

Given that greater business cycle coordination among EMU Member States is an acknowledged means to increase effectiveness of policies, the presence of a core periphery dualism could have represented an obstacle to the effectiveness of European economic policies in general and to the process to meet the 17 Goals.

The paper is organized as follows. Section 2 presents the result of the cluster analysis to identify a core periphery dualism in EMU countries for the SDGs dimension. In Section 3 data and econometric strategy to estimate the impact of SDGs scores similarity on EMU countries cyclical correlation are described, Section 4 reports the comments to the estimates. Conclusions follow.

2 SDGs as a new dimension of core periphery dualism in EMU?

In order to assess whether a Core-Periphery dualism can be identified also in the SDGs data and metrics for 12 EMU countries in the period 2001-2022[7], we use the scores provided at Goal level by the Bertelsmann Stiftung and the Sustainable Development Solutions Network (SDSN)[8] (Sachs et al. 2022, Lafortune et al. 2018).

[6] The optimality of a currency area (OCA) is thus a function of the relative "distance" between its members. If these differentials are large, it is common to speak of a core and a periphery. It is expected that core countries would be those more closely meeting the OCA criteria. Given its importance for OCA, it is not surprising there have been various attempts of classifying countries into the core and periphery sets. A basic way of distinguishing these methods is whether or not the Core-Periphery status is imposed a priori. A statistical technique often used here is cluster analysis.

[7] In our analysis we consider the 12 European countries which were EMU members in 2001 that is: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, The Netherlands, Portugal and Spain. The sensitivity analysis performed showed that, considering the overall SDG Index, our findings are robust also including the other 7 countries which joined the EMU until 2022 and UK, Switzerland and Norway (see Table A.3).

[8] Published since 2015, the SDG Index and Dashboards has been peer-reviewed and statistically audited by the European Commission.

Bertelsmann Stiftung and the SDSN compute scores, also retrospectively starting from 2000, to assess each country's overall performance on each of the 17 SDGs. The score for each Goal estimates absolute country performance based on a normalized distance to invariant sustainable development targets, i.e., "technical optimums" chosen by a five-steps decision tree (Lafortune et al. 2018). Each score indicates a country's position between the worst possible outcome (score of 0) and the target (score of 100). Therefore, scores by Goal can be interpreted as the percentage of achievement (i.e. the difference between 100 and countries' scores is the distance in percentage that needs to be completed to achieving the Goals). A general SDG score (SDG Index) is also computed, as the arithmetic mean of the 17 SDGs scores[9].

We also aggregate the 17 Goals in 3 categories (People, Planet, Prosperity,) in line with "The Resolution adopted by the General Assembly on 25 September 2015 on the 2030 Agenda for Sustainable Development" which established three main pillars for its plan of action. Even if there is no unanimous agreement on re-organizing the 17 goals into these three categories, it is customary (Istat 2022) to combine the Goals[10] in this way: People includes Goals from 1 to 5, Prosperity from 7 to 11, Planet includes goal 6 and then from 12 to 15. Goals 16 and 17 are usually considered standalone given their peculiar features.

In this paper we applied a clustering procedure (Bacchini et al., 2020) based on Jenks's natural breaks (Jenks, 1977) to the 3 UN Pillars (3P henceforth) in order to analyze whether a Core-Periphery pattern can be detected. We excluded from our analysis Peace and Partnerships since the two related Goals refer to indicators with very different features with respect to the others, therefore we sticked to the tripartite model first established by the Brundtland Report (Brundtland 1987, Bergman et al. 2018).

According to the relevant literature, natural breaks are in general more informative than just resorting to quantiles (see Baldazzi et al. 2019). Natural breaks classes aggregate similar values, maximizing the variance between groups and minimizing the variance within groups[11]. We evaluate countries' trends over time under the 3P, from 2001, in order to include Greece among our sample of EMU countries, and up to 2022[12], also measuring their convergence within and between groups.

We opted to evaluate convergence by simply tracking the intertemporal change in the coefficient of variation[13] of the given composite score. This methodology, proposed by Friedman (Friedman 1992) and labelled σ-convergence by Sala-i-Martin (Sala-i-Martin 1996), has the indisputable advantage of being a simple non-parametric and unbiased index that relates to whether or not the cross-regional disparities shrink over time (Boyle and McCarthy 1997). It was extensively used to study the regional/territorial evolution of the main SDGs indicator (for

[9] Data used to compute the scores come from official statistics (typically UN custodian agencies) and from non-traditional statistics, including research centres, universities, and non-governmental organizations.

[10] "No Poverty" (Goal 1), "Zero Hunger" (Goal 2), "Good Health and Well-being" (Goal 3), "Quality Education" (Goal 4) and "Gender Equality" (Goal 5) (category "People"); "Decent Work and Economic Growth" (Goal 8), "Industry, Innovation and Infrastructure" (Goal 9), "Reduced Inequality" (Goal 10), "Sustainable Cities and Communities" (Goal 11) (category "Prosperity"); "Clean Water and Sanitation" (Goal 6) , "Affordable and Clean Energy" (Goal 7), "Responsible Consumption and Production" (Goal 12), "Climate Action" (Goal 13), "Life Below Water" (Goal 14) and "Life on Land" (Goal 15) (category "Planet"); "Peace, Justice and Strong Institutions" (Goal 16) and "Partnerships for the Goals" (Goal 17) are usually considered standalone Goals.

[11] In particular, class breaks are chosen in order to minimize the sum of the squared deviations from the class means, thus classes might have very different ranges and/or sizes but they usually show a low internal variability. Computations were made in R and based on the function classIntervals (with the option style="jenks") from the package classInt (Bivand at al., 2019).

[12] Score for Goal 14 is not available yet for Austria and Luxembourg for 2022, we used 2021 data instead.

[13] The coefficient of variation at time t is $CV_t = 100 \cdot \frac{\sigma_t}{|\mu_t|} = 100 \cdot \frac{\sqrt{\frac{1}{\#Cou}\sum_{i\,\epsilon\,Cou}(x_{i,t}-\mu_t)^2}}{|\mu_t|}$,

where $x_{i,t}$ is the score for country i at time t, $\mu_t$is the mean over i of all $x_{i,t}$'s and $\sigma_t = \sqrt{\frac{1}{\#Cou}\sum_{i\,\epsilon\,Cou}(x_{i,t}-\mu_t)^2}$ is the standard deviation at time t of all $x_{i,t}$'s. Cou is the set of countries under consideration.

example Ferrara Nisticò 2013, Marchante et al. 2006, Simionescu 2014, Chelli et al. 2022, UNESCAP 2017, Istat 2021, Istat 2022, Istat 2023)[14].

For the general SDG Index and for each of the three UN pillars, we classified countries in the two groups Core/Periphery by simply applying a clustering procedure based on two classes. The results for 2001, 2011 and 2022 are reported in Table 1.

Table 1 Core and periphery countries 2001-2022

	2001		2011		2022	
	Periphery	Core	Periphery	Core	Periphery	Core
SDG Index	Belgium Greece Italy Luxembourg Portugal Spain	Austria Finland France Germany Ireland The Neth.	*the same as 2001*		+Ireland +The Neth.	-Ireland -The Neth.
People	Austria Belgium Greece Italy Luxembourg Portugal Spain	Finland France Germany Ireland The Neth.	-Austria -Belgium	+Austria +Belgium	*the same as 2011*	
Prosperity	Greece Italy Luxembourg Portugal Spain	Austria Belgium Finland France Germany Ireland The Neth.	*the same as 2001*		*the same as 2001 and 2011*	
Planet	Belgium Luxembourg	Austria Finland France Germany Greece Italy Ireland The Neth. Portugal Spain	+Austria +France +Germany +The Neth.	-Austria -France -Germany -The Neth.	-France -Germany	+France +Germany

We can see that the classification is fairly persistent during time, especially for the Prosperity dimension. Results are largely consistent with the existing literature (see Table 1 in the appendix). In particular, considering the general SDG Index, we can identify Austria, Finland, France, Germany as Core countries, and Greece, Italy, Portugal, Spain as Periphery countries.

We performed a sensitivity analysis which proved our Core-Periphery taxonomy to be fairly robust and the preferred choice. A clustering procedure based on three classes (Core/Intermediate/Periphery) proved to be sensible to outliers (e.g., for the general SDG Index, the Core group would consist only of Finland). A clustering procedure based on four or five

[14] We did not use the β-convergence (Sala-i-Martin 1996) since it requires economic assumptions which are not appropriate for social or environmental indicators.

classes (two upper Core classes, possibly an Intermediate class and two lower Periphery classes) provided similar results as in Table 1[15].

Table 2 SDGs as a new dimension of the Core-Periphery dualism

		2001		2022		Change (%)		distance Core-Periphery		
		mean	cv	mean	cv	mean	cv	2001	2022	diff (%)
SDG Index	Periphery	71.5	2.2	78.3	2.0	9.5%	-9.3%	3.82	2.40	-37.2%
	Core	77.1	3.3	82.1	2.6	6.5%	-20.4%			
	Total	74.3	4.7	80.2	3.3	7.9%	-29.7%			
People	Periphery	81.0	2.2	87.0	2.1	7.4%	-6.1%	2.96	1.34	-54.8%
	Core	85.9	1.1	89.4	0.7	4.0%	-30.3%			
	Total	83.0	3.4	88.0	2.1	5.9%	-38.5%			
Prosperity	Periphery	69.2	5.6	79.3	3.4	14.6%	-38.7%	7.49	5.18	-30.8%
	Core	80.5	3.3	88.0	2.7	9.4%	-17.9%			
	Total	75.8	8.4	84.4	5.9	11.4%	-30.3%			
Planet	Periphery	56.9	3.0	62.2	3.0	9.3%	-2.2%	7.87	7.02	-10.9%
	Core	66.7	5.1	71.6	5.0	7.4%	-2.5%			
	Total	65.0	7.4	70.0	6.9	7.7%	-6.9%			

Note: the distance is computed as the absolute difference between the core and periphery average values divided by the sum of the two values and multiplied by 100.

Using four classes, France is classified as Periphery, but that is peculiar of 2001, from 2008 onwards France falls again in the Core category. Using five classes, France and Spain would sometime be classified as intermediate, but overall, considering the whole time span, and eventually wanting to divide the countries in the two final categories, France would be considered a Core country and Spain a Periphery country.

In Table 2 some descriptive statistics are reported with the 2001 classification, in order to measure the intra- and inter-dynamics of the two groups. The polarization is evident, whether we consider a composite SDG indicator or if we disentangle for the 3Ps. Moreover, the dualism has changed considerably in the period 2001-2022, both in terms of relative strengths and distances between main groups of countries, but also in terms of the trajectories of individual countries (Figure A1 in the Appendix).

The data show that there is evidence of a Core-Periphery pattern over the period of analysis although the distance between the two groups has been diminishing especially for the People dimension (see Table 2 and Figure A1 in the Appendix). The C-P is evident for the aggregate index and for the 3Ps dimensions, but the polarization is more evident for People and Prosperity rather than for Planet. The coefficient of variation (see note 11), which measures the dispersion of the data around the mean, displays for the aggregate SDG index a stronger reduction for the core countries than for the periphery.

3. Empirical test of the relationships between SDGs and imbalances: econometric strategy and data

Since the study of Frankel and Rose (1998) a large body of empirical research (Clark and van Wincoop, 2001; Calderon et al., 2007, Caporale et al 2014 among others) has shown that bilateral trade flows can affect output synchronization across countries and/or regions[16]. The

[15] See Table A.1 in the appendix for the general SDG Index

[16] According to standard theory, trade intensity has an ambiguous effect on the co-movement of output. Openness to trade could lead to increased specialization in production (inter-industry patterns of trade) or to more similar production mainly due to scale economies (intra-industry trade). If business cycles are hit by industry-specific shocks and trade-induced specialization dominates, this leads to decreasing business cycle correlations. However, if trade is dominated by intra-industry trade industry-specific shocks may lead to more symmetric business cycles. Consequently, the positive link between trade and business cycle synchronization is often seen as an indication that intra-industry dominates inter-industry trade as a spillover channel for shocks.

positive effect of bilateral trade flows on the degree of international business cycle synchronization has been widely confirmed in the literature even when controlling for other possible determinants, such as capital flows, foreign direct investments or industry specialization (Böwer and Guillemineau 2006; Inklaar et al., 2008; Azcona, 2022). In particular, given the important role of mutual financial flows within the European Union we include in our analysis some measures of financial integration (Imbs, 2010; Kalemli-Ozcan et al.,2013a, 2013b).

To take into account the pattern of SDG scores on business cycle correlation we augment the canonical model as in the following equation:

$$BCS_{i,j,t} = \alpha + \beta_1 TRint_{i,j,t-1} + \beta_2 FDIint_{i,j,t-1} + \beta_3 PTFint_{i,j,t-1} + \beta_4 SDGs_{i,j,t-1} + \delta_i \theta_t + \mu_j \theta_t + \varepsilon_{i,j,t} \quad (1)$$

Where BCS is a measure of business cycle synchronization between country *i* and country *j*, *TRint* measures trade integration, *FDIint* and *PTFint* are the two dimensions of financial integration measures, i.e., foreign direct investment and portfolio investment. SDGs is a measure of similarity in SDG scores.

We add to the equation a full set of dummies for country *i* and country *j* interacted with time dummies.

To assess whether the relationship between output synchronization and SDGs follows a Core-Periphery pattern, we estimate the following equation:

$$BCS_{i,j,t} = \alpha + \beta_1 TRint_{i,j,t-1} + \beta_2 FDIint_{i,j,t-1} + \beta_3 PTFint_{i,j,t-1} + \beta_4 SDGs_{i,j,t-1} x Group_{i,j} + \delta_i \theta_t + \mu_j \theta_t + \varepsilon_{i,j,t} \quad (2)$$

Where *Group* is a set of dummies for the macro-regions of countries *i* and *j*. Categories are: Core vs Core; Core vs Periphery; and Periphery vs Periphery.

Equations (1) and (2) are estimated using a Random Effects model in line with the existing literature.

Core and Periphery grouping is based on classification of Esposito and Messori (2018) which includes in the periphery the so called GIIPS (Greece, Ireland, Italy, Portugal, Spain) and in the core Austria, Belgium, Finland, France, Germany, the Netherlands. We performed a sensitivity analysis using other two definitions: i) the classification of Artis and Zhang (2001) which, compared to Esposito and Messori (2018) includes Ireland in the Core group and ii) the SDG-based classification reported in the first panel of Table 1 for 2001 (see also Table A1 in the Appendix).

All regressors are lagged by one period to reduce endogeneity issues[17]. To shed light on this issue, we perform Granger causality tests based on a panel VAR approach (Zecchino and Love, 2016). A panel unit root test is also performed to assess whether series are stationary and can thus be introduced in levels without having to model co-integration.

[17] As a matter of fact, output synchronization is likely to affect the patters of SDG scores as the availability of resources to implement the policies related to the goals depends on the overall growth pattern and business cycle fluctuations, thus reverse causality is not ruled out.

The dataset (see Table A4 in the Appendix for data summary statistics) includes the 12 EU countries that first adopted the euro in 2002 over the years 2003-2019.[18]

To measure business cycle synchronization, we use two different measures. The first one is the negative of the absolute difference in the cyclical components of country *i*'s and country *j*'s GDP growth:

$$BCS1 = -|cyc_{i,t} - cyc_{j,t}| \quad (3)$$

Cyclical components have been extracted using the Hodrick-Prescott filter. The second measure is given by the residuals of a regression of growth rates on both countries and year fixed effects (Morgan et al. 2004; Caporale et al., 2014):

$$BCS2 = -|\gamma_{i,t} - \gamma_{j,t}| \quad (4)$$

With $g_{i,t} = \delta_i + \theta_t + \gamma_{i,t}$.

Trade and financial integration are measured as the ratio of bilateral trade, FDI and Portfolio investment flows over the sum of country pairs' GDPs. To measure convergence/divergence in SDG scores we use a similar approach to equation (1), that is the negative of the absolute difference in SDG scores for country *i* and country *j*:

$$SDG^k_{i,j,t} = -|SDG^k_{i,t} - SDG^k_{j,t}| \quad (5)$$

With *k*=total SDGs (SDG), Prosperity (PROSP), Planet (PLAN) and People (PEOP).

Data are from different sources. The SDG indicators are taken from the Bertelsmann Stiftung and the Sustainable Development Solutions Network (SDSN). Data on GDP growth are from Eurostat whereas data on bilateral trade flows are from the Eurostat-COMEXT database. Finally, data on bilateral FDI and portfolio investment are from the JRC-ECFIN Finflows database.

4. Estimation results

In Tables 3 and 4 the results of unit root and Granger causality tests are reported.

Table 3 Unit Root Test

	P&S 2003
BCS1	-1.1*
BCS2	-4.3***
TRint	-1.5*
FDIint	-3.7**
PTFint	-3.6***
SDG	-1.6*
PROSP	-2-2**
PEOP	-4.2***
PLAN	-4.6***

Standard errors in brackets. * Significant at 10% level; **significant at 5% level; ***significant at 1% level.

The Pesaran and Shin (2003) tests for heterogenous unbalanced panels shows that all series are stationary, thus they can be introduced without first differencing both in the Panel VAR-based Granger causality tests and in the panel data estimates.

[18] Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, The Netherlands, Portugal and Spain. We exclude Luxemburg from the sample because of its role as financial center that can bias the estimates.

Table 4 shows that Granger causality goes from SDGs to output synchronization when the total SDG score is tested against measures BCS1 and BCS2.

As for PROSP both causality relationships seem to be at work whereas BCSs seem to cause PEOP. Finally, for PLAN the results are more uncertain as there is causality from PLAN to fgBCS1 and bidirectional causality with BCS2.

Table 4 Granger causality between output synchronization (x) and SDGs convergence/divergence (y)

x/y	SDG	PROSP	PEOP	PLAN
BCS1	y to x	x to y; y to x	x to y; y to x	y to x
BCS2	y to x	y to x	x to y	x to y; y to x

There is evidence that SDGs similarity affects output synchronization, especially for the overall score, but for the individual components both directions of causality are likely to be at work. Estimates can thus be affected by this issue although the introduction of lagged regressors should mitigate this problem. All in all, we cannot assume that the estimated coefficient is a causal effect and not a correlation.

In Table 5, we show estimates results of equation (1) with respect to the two different measures of business cycle synchronization. Bilateral trade and financial flows are positively related to BCS, in line with the prevailing literature (Inklaar et al., 2008, Kalemli-Ozcan et al. 2013b, Caporale et al 2014), while foreign direct investments flows show negative but not statistically significant coefficients.

Table 5 Business cycle synchronization and convergence in SDGs and components

	BCS1				BCS2			
$TRint_{t-1}$	0.051**	0.042**	0.019	0.048**	0.042**	0.036**	0.018	0.041**
	[0.019]	[0.016]	[0.015]	[0.017]	[0.017]	[0.017]	[0.018]	[0.018]
$FDIInt_{t-1}$	-0.017	-0.017	-0.012	-0.016	-0.032	-0.032	-0.029	-0.032
	[0.018]	[0.019]	[0.024]	[0.019]	[0.023]	[0.023]	[0.023]	[0.023]
$PTFint_{t-1}$	0.099***	0.097**	0.090**	0.099***	-0.062	-0.065	-0.069	-0.063
	[0.029]	[0.029]	[0.029]	[0.029]	[0.056]	[0.055]	[0.055]	[0.056]
SDG_{t-1}	0.002				0.014			
	[0.028]				[0.020]			
$PROSP_{t-1}$		0.022**				0.014*		
		[0.011]				[0.007]		
$PLAN_{t-1}$			-0.062**				-0.045***	
			[0.019]				[0.013]	
$PEOPLE_{t-1}$				-0.037				-0.018
				[0.027]				[0.018]
R^2w	0.885	0.884	0.885	0.884	0.889	0.889	0.889	0.889
N	1948	1948	1948	1948	1948	1948	1948	1948

Standard errors in brackets. * Significant at 10% level; **significant at 5% level; ***significant at 1% level.

The coefficient of SDGs similarity index is positive but not statistically significant. However, if we disentangle SDGs in its three components Prosperity (PROSP) coefficient is positive and significant for both measures of output synchronization suggesting that greater similarity between Prosperity scores for countries pair is positively associated to a greater business synchronization whereas the opposite occurs for Planet (PLAN). As for People (PEOP), the coefficient is negative but not statistically significant.

In Table 6, we show the results of equation (2) using the overall SDG similarity index and its interaction with Core and Periphery country pairs. The interaction terms return separate coefficients for each of the three groups of countries pairs (CC=Core-Core; CP=Core-Periphery; PP=Periphery-Periphery).

For Core-Core pairs, an increase in the similarity of SDG indices is associated with higher output synchronization. This result is confirmed by both measures of synchronization. As for the other groups, the coefficient of SDG similarity is not significant for Core-Periphery pairs whereas for Periphery-Periphery pairs the coefficient turns negative (in the case of BCS2)[19].

Table 6 Business cycle synchronization and SDG convergence by Core-Periphery groups

	BCS1	BCS2
$TRint_{t-1}$	0.006	-0.004
	[0.012]	[0.012]
$FDIInt_{t-1}$	-0.003	-0.011
	[0.021]	[0.023]
$PTFint_{t-1}$	0.093***	-0.065
	[0.027]	[0.059]
SDG_{t-1}*CC	0.082**	0.067**
	[0.027]	[0.023]
SDG_{t-1}*CP1	-0.009	-0.003
	[0.012]	[0.010]
SDG_{t-1}*PP1	0.002	-0.053***
	[0.020]	[0.008]
R^2w	0.885	0.888
N	1948	1948

Standard errors in brackets. * Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Looking at the 3Ps of the SDGs index for the three different country pairs in Table 7 (CC, CP and PP) we notice that Prosperity is positively associated with business synchronization, whereas for Planet we find a negative relationship with BCSs when the pair is Core-Core or Core-Periphery (BCS2) although the negative coefficient is of greater magnitude for Core-Core pairs.

PEOPLE is associated negatively to output synchronization among Core-Core pairs whereas the relation turns positive for Core-Periphery pairs and for Periphery-Periphery pairs[20].

[19] These results proved to be robust to a change in core periphery groups definition according to Artis and Zhang (2001) and the SDG based classification (see Sect. 3).

[20] Tables A5 and A6 show the same specification following, respectively, the Core-Periphery classifications 2 and

Table 7 Relationship between business cycle synchronization and convergence in SDG components by Core-Periphery group 1

	BCS1			BCS2		
	1	2	3	4	5	6
$TRint_{t-1}$	0.003	0.000	0.033**	0.002	0.000	0.014
	[0.012]	[0.011]	[0.015]	[0.012]	[0.014]	[0.012]
$FDIInt_{t-1}$	-0.011	-0.005	-0.016	-0.013	-0.019	-0.008
	[0.020]	[0.024]	[0.017]	[0.024]	[0.023]	[0.024]
$PTFint_{t-1}$	0.092***	0.085**	0.095***	-0.067	-0.071	-0.055
	[0.027]	[0.027]	[0.028]	[0.060]	[0.055]	[0.056]
$PROSP_{t-1}$*CC	0.109***			0.032*		
	[0.022]			[0.017]		
$PROSP_{t-1}$*CP1	0.006			-0.014		
	[0.013]			[0.010]		
$PROSP_{t-1}$*PP1	0.008			-0.062***		
	[0.026]			[0.013]		
$PLAN_{t-1}$*CC		-0.064***			-0.040***	
		[0.013]			[0.010]	
$PLAN_{t-1}$*CP1		-0.043**			-0.016	
		[0.022]			[0.014]	
$PLAN_{t-1}$*PP1		-0.081			0.048	
		[0.055]			[0.076]	
$PEOPLE_{t-1}$*CC			0.063			-0.075*
			[0.053]			[0.044]
$PEOPLE_{t-1}$*CP1			-0.03			0.053**
			[0.032]			[0.023]
$PEOPLE_{t-1}$*PP1			-0.013			0.127***
			[0.073]			[0.020]
R^2	0.885	0.885	0.885	0.888	0.889	0.888
N	1948	1948	1948	1948	1948	1948

Standard errors in brackets. * Significant at 10% level; **significant at 5% level; significant at 1% level.

Conclusions

The cluster analysis performed in this paper evidenced that there was a Core-Periphery pattern for SDGs scores in the period 2001-2021 for 12 EMU countries, although the distance between and within the two groups diminished overtime. The splitting of countries into two groups according to the general SDGs Index and two of its main components (People and Prosperity) is fairly consistent with the grouping proposed by the literature on core periphery dualism in EMU.

Moreover, panel estimates for the period 2003-2019 evidenced that there was a relationship between SDGs scores similarity and business cycle synchronization for the selected 12 EMU countries. According to our estimates, in fact, it seems that having a similar pattern to reach the SDGs had differentiated associations on core and periphery countries business cycles thus accentuating the dualism. Moreover, disentangling the SDGs similarity index in its three main components (the 3Ps) evidenced heterogeneous and even opposite relationships with business cycle correlation: Prosperity score similarity, analogously to the general index, seems to have accentuated the dualism while for Planet the association with BCS was negative for both core

and periphery pairs but the coefficient for periphery is lower thus somehow suggesting a reduction of the dualism. Eventually, it seems that People score similarity also weakened the dualism.

These heterogeneous results, once we disentangle the composite SDG index, seems to be consistent with the acknowledged presence of trade-offs, synergies and externalities between and within the SDGs and especially between Prosperity and Planet dimensions.

Appendix

Table A1 – Core periphery countries in Europe: main classification in literature

Author	Empirical strategy	Core and periphery countries
Artis and Zhang (2001, 2002)	Clustering technique	**Core**: Germany, France, Austria, Belgium and the Netherlands, **Northern periphery**: Denmark, Ireland, the UK, Switzerland, Sweden, Norway and Finland) **Southern periphery**: Spain, Italy, Portugal and Greece
Bayoumi and Eichengreen (1993)	Theory based approach	**Core**: Germany, Austria, Belgium, the Netherlands, Ireland and Switzerland. **Intermediate**: UK Denmark, Finland, Norway and France. **Periphery**: Sweden, Italy, Greece, Portugal and Spain
Basse (2014)	Cointegration and structural breaks	**Core**: Germany, Belgium, Austria, Finland, and the Netherlands. France: uncertain.
Nauros and Macchiarelli (2016)	Structural VAR	**Core:** Germany, France, Belgium, Netherlands and Denmark **Periphery:** Ireland, Spain, Greece and Portugal
Nauros and Macchiarelli (2021)	Phillips-Sul (2007) procedure, dynamic analysis.	**Hard-core**: Austria, Belgium, Germany, and the Netherlands, **Soft-core**: France, Italy, Denmark, Spain, and the UK, **Extended periphery**: Greece, Sweden, Finland, Ireland, Norway, Portugal and Switzerland.

Figure A1 – SDG Score 2001-2022, by countries

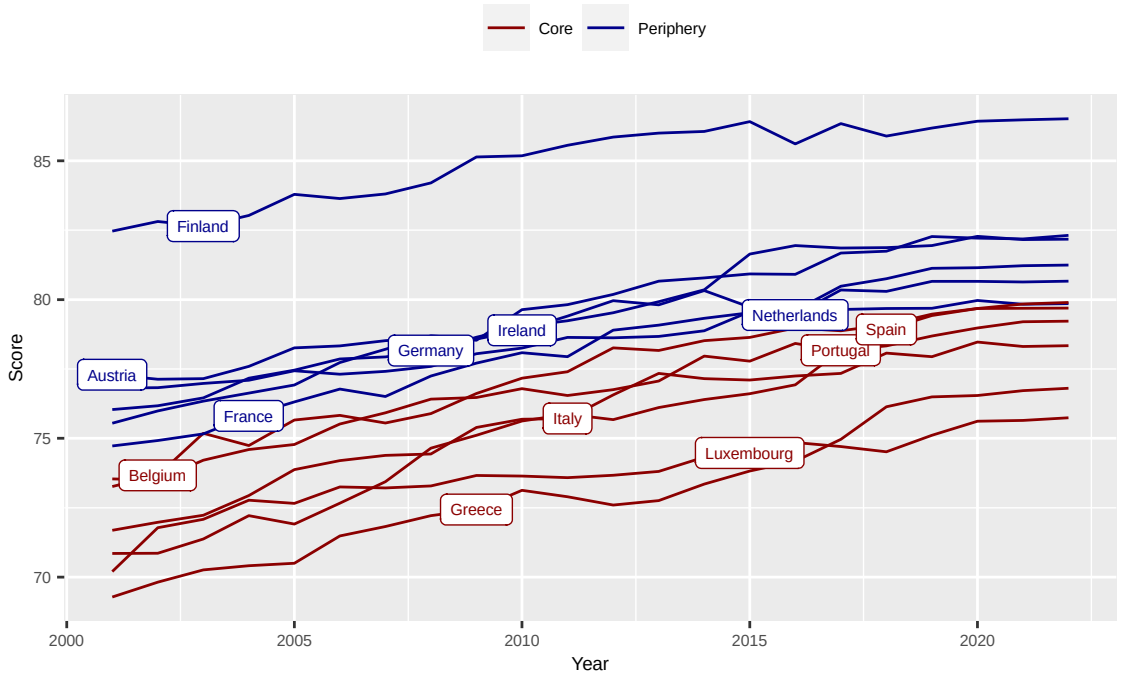

Table A2 – Classification of countries between Core and Periphery, based on Jenks natural breaks clustering procedure, applied to SDG Index in 2001

	2 classes	3 classes	4 classes	5 classes
Austria	core	neutral	core	core
Belgium	periphery	intermediate(per)	periphery	intermediate(per)
Finland	core	core	core	core
France	core	intermediate	periphery	intermediate(core)
Germany	core	intermediate	core	core
Greece	periphery	periphery	periphery	periphery
Ireland	core	intermediate	core	core
Italy	periphery	periphery	periphery	periphery
Luxembourg	periphery	periphery	periphery	periphery
The Neth.	core	intermediate	core	core
Portugal	periphery	periphery	periphery	periphery
Spain	periphery	intermediate(per)	periphery	intermediate(per)
GVF	64.8%	88.2%	98.2%	99.1%

Note: when a country falls in the intermediate class the tendency to be core or periphery in the whole period 2001-2022 is reported in brackets. GVF (Goodness of Variance Fit) is the percentage of the total sum of squared deviations from the mean explained by the clustering.

Table A3 – Core and Periphery countries for EMU members in 2001, non-considering (left) or considering (right) the other EMU countries (2022) and Norway, Switzerland and UK

	2001		2001	
	Periphery	Core	Periphery	Core
SDG Index	Belgium Greece Italy Luxembourg Portugal Spain	Austria Finland France Germany Ireland Netherlands	*same*	
People	Austria Belgium Greece Italy Luxembourg Portugal Spain	Finland France Germany Ireland The Neth.	-Austria -Belgium -Spain	+Austria +Belgium +Spain
Prosperity	Greece Italy Luxembourg Portugal Spain	Austria Belgium Finland France Germany Ireland The Neth.	*same*	
Planet	Belgium Luxembourg	Austria Finland France Germany Greece Italy Ireland The Neth. Portugal Spain	+Austria +France +Germany +Greece +Ireland +Italy +Netherlands +Portugal +Spain	-Austria -France -Germany -Greece -Ireland -Italy -Netherlands -Portugal -Spain

Figure A2 – Average Core and Periphery scores, with standard deviation bands

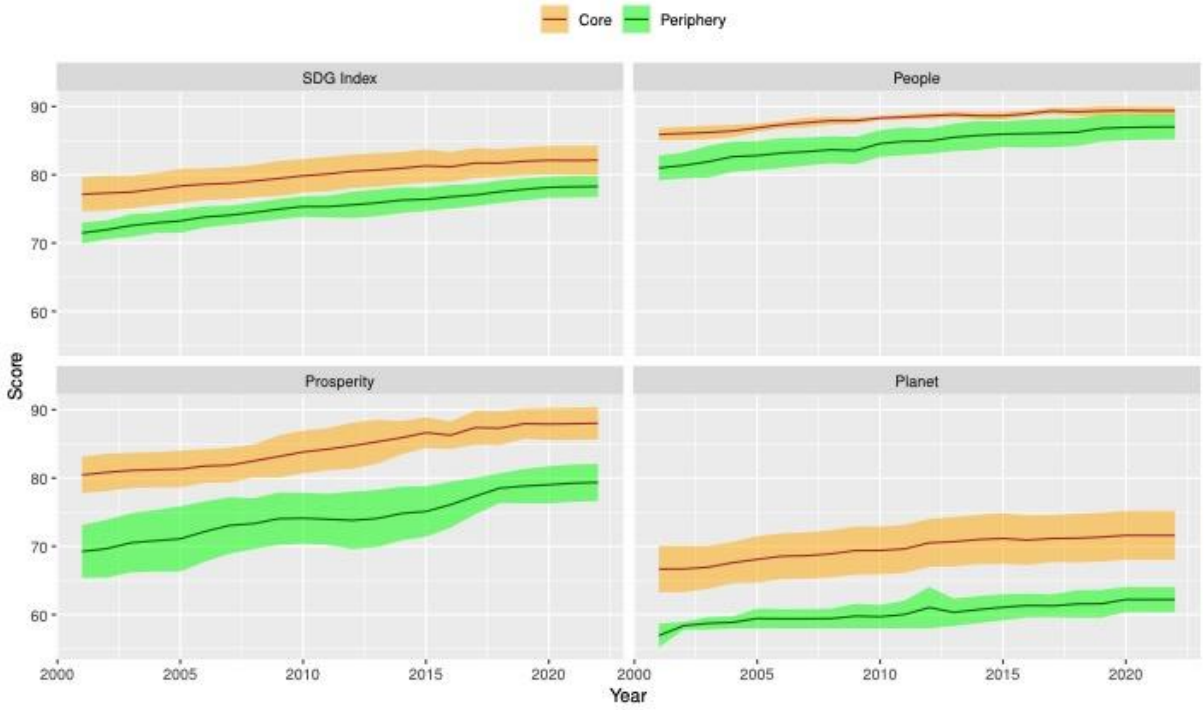

Table A4 Data source and descriptive statistics

	Mean	SD	Min	Max
BCS1	-0.01673	0.020445	-0.09799	0
BCS2	-0.02003	0.025788	-0.17842	0
TRint	0.016134	0.021999	0.000572	0.219785
FDIint	0.013944	0.063897	-0.6511	0.575059
PTFint	0.012176	0.053596	-0.26258	0.466121
SDG	-0.034	0.026912	-0.13285	0
PROSP	-0.07207	0.051671	-0.25477	0
PEOPLE	0.026375	0.021424	0.000034	0.09749
PLANET	0.048458	0.034788	0.000215	0.164622

Source: Eurostat, COMEXT, European Commission; Bertlesmann Stiftung.

Table A5 Relationship between business cycle synchronization and convergence in SDG components by Core-Periphery group 2

	BCS1			BCS2		
	1	2	3	1	2	3
$TRint_{t-1}$	0.022*	-0.003	0.027**	0.031*	0.012	0.036**
	[0.013]	[0.011]	[0.013]	[0.018]	[0.019]	[0.017]
$FDIInt_{t-1}$	-0.018	-0.01	-0.016	-0.034	-0.028	-0.032
	[0.019]	[0.024]	[0.019]	[0.023]	[0.023]	[0.023]
$PTFint_{t-1}$	0.093**	0.078**	0.087**	-0.059	-0.075	-0.064
	[0.030]	[0.029]	[0.030]	[0.054]	[0.053]	[0.055]
$PROSP_{t-1}$*CC	0.032			0.050**		
	[0.021]			[0.022]		
$PROSP_{t-1}$*CP2	-0.016			0.023		
	[0.021]			[0.020]		
$PROSP_{t-1}$*PP2	-0.044			-0.032		
	[0.044]			[0.043]		
$PLAN_{t-1}$*CC		-0.044**			-0.040***	
		[0.015]			[0.012]	
$PLAN_{t-1}$*CP2		-0.029			-0.065***	
		[0.020]			[0.014]	
$PLAN_{t-1}$*PP2		-0.159***			0.810	
		[0.058]			[0.066]	
$PEOPLE_{t-1}$*CC			0.012			0.005
			[0.051]			[0.040]
$PEOPLE_{t-1}$*CP2			0.066			0.014
			[0.087]			[0.053]
$PEOPLE_{t-1}$*PP2			-0.004			0.044
			[0.111]			[0.064]
R^2	0.886	0.887	0.886	0.888	0.889	0.888
N	1948	1948	1948	1948	1948	1948

Standard errors in brackets. * Significant at 10% level; **significant at 5% level; significant at 1% level.

Table A6 Relationship between business cycle synchronization and convergence in SDG components by Core-Periphery group 3

	BCS1			BCS2		
	1	2	3	1	2	3
$TRint_{t-1}$	0.045**	-0.004	0.049**	0.034**	0.017	0.038**
	[0.017]	[0.012]	[0.018]	[0.016]	[0.019]	[0.017]
$FDIInt_{t-1}$	-0.017	-0.008	-0.015	-0.035	-0.026	-0.029
	[0.019]	[0.024]	[0.019]	[0.024]	[0.024]	[0.023]
$PTFint_{t-1}$	0.096**	0.081**	0.095**	-0.063	-0.071	-0.064
	[0.030]	[0.029]	[0.029]	[0.054]	[0.054]	[0.055]
$PROSP_{t-1}$	0.028			0.050**		
	[0.020]			[0.020]		
$PROSP_{t-1}$*CP3	0.015			-0.024		
	[0.019]			[0.019]		
$PROSP_{t-1}$*PP3	0.020			-0.058**		
	[0.029]			[0.025]		
$PLAN_{t-1}$		-0.037**			-0.033**	
		[0.017]			[0.013]	
$PLAN_{t-1}$*CP3		-0.055*			-0.056***	
		[0.029]			[0.014]	
$PLAN_{t-1}$*PP3		-0.160***			-0.041*	
		[0.026]			[0.023]	
$PEOPLE_{t-1}$			0.001			0.039
			[0.059]			[0.043]
$PEOPLE_{t-1}$*CP3			-0.014			-0.037
			[0.076]			[0.055]
$PEOPLE_{t-1}$*PP3			-0.105			-0.028
			[0.088]			[0.049]
R^2	0.884	0.887	0.885	0.889	0.889	0.889
N	1948	1948	1948	1948	1948	1948

Standard errors in brackets. * Significant at 10% level; **significant at 5% level; significant at 1% level.

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