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"Un-sustainable" Development Goals as a New Dimension of the European Monetary Union Core-periphery Dualism

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Roberta De Santis, Lorenzo Di Biagio and Piero Esposito*

Abstract

While the persistent core-periphery dualism within the European Monetary Union (EMU) has been extensively studied, its relationship to the Sustainable Development Goals (SDGs) remains unexplored. This is surprising, given the EU's strong commitment to achieving the 17 SDGs by 2030. The SDGs encompass a broad range of economic, social and environmental targets and the pursuit of these goals through targeted economic policies could have significant macroeconomic implications and redistributive effects at country and region level.

This research fills this critical gap by investigating two key questions: (1) Do the SDGs themselves reflect a new dimension of the so-called EMU core-periphery dualism? (2) How have changes in SDG scores for EMU country pairs influenced the existing core-periphery dualism? Our findings shed light on the interaction between the SDGs and the EMU's internal cohesion, offering preliminary interesting policy insights.

Keywords: Euro, Core-periphery, Convergence, Sustainable development

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

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“Un-sustainable” Development Goals as a New Dimension of the European Monetary Union Core-periphery Dualism

1. Introduction

The European Union (EU) took a leading role in shaping and adopting the United Nations (UN) Agenda 2030 for sustainable development. Since 2015, the European Commission has been particularly active in integrating the 17 Sustainable Development Goals (SDGs) into various policies for member states (Borchardt *et al.*, 2023). However, the SDGs, which encompass diverse economic, social and environmental targets, present a complex challenge; and integrating them through national and international policies may have had macroeconomic and redistributive consequences within and between countries. Within a highly integrated zone like the European Monetary Union (EMU), Agenda 2030 implementation could have influenced cyclical correlations between member states, potentially impacting the effectiveness of common policies. Notably, the EMU has long struggled with a persistent "core-periphery" dualism among its members.

Despite recognizing this issue's significance, to the best of our knowledge no empirical research explores whether the core-periphery dynamic affects progress towards the SDGs, or if the SDGs themselves could introduce a new dimension to the core-periphery dualism. This gap in the literature is concerning, given the strong commitment of the EU and its member states to the 2030 Agenda[1].

The core-periphery dualism was initially acknowledged by Bayoumi and Eichengreen

[1] See "Next steps for a sustainable European future" communication (EC, 2016) and “Towards a sustainable Europe by 2030” (EC, 2019).

(1993), who identified this pattern in the process towards the creation of the EMU[2]. With the framework of the optimal currency area theory, the authors categorized demand and supply shocks using long-run restrictions in a structural framework. They found "core" countries where supply-side shocks are highly correlated (Germany, France, Belgium, the Netherlands and Denmark) and "periphery" countries where shocks are uncorrelated (Greece, Ireland, Portugal, Spain, Italy and the UK). Bayoumi and Eichengreen (1993) suggested that if persistent, these countries' polarization would have been detrimental to the well-functioning of the EMU, especially given the one-size-fits-all monetary policy and the bounded fiscal policies.

This seminal paper has sparked an intense, three-decade-long debate among economists over the causes and consequences of the core-periphery dualism (De Grauwe 2018). Several studies sought to precisely define the two groups of countries, also using dynamic approaches to study their changes over time (Campos and Macchiarelli 2021). In addition, many papers empirically assessed the presence of a core-periphery 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).

In the literature there are only a few empirical papers testing the relationship between the core-periphery dualism in the EMU and the social and economic indicators included in the SDGs, such as income inequality, institutional quality and migration flows (Cesaroni, D'Elia and De Santis 2019; Esposito, Collignon and Scicchitano 2020).

Notably, a paper by Bacchini, Cannata and Donà (2020) that used the Macroeconomic Imbalance procedure scoreboard[3], and thus considered social and development indicators also included in the SDGs, evidenced that economic and financial crises

[2] On the contrary, Frankel and Rose, 1998, in line with 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 that 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 "specialization" (Krugman and Venables, 1995).

[3] The MIP scoreboard includes 14 headline indicators plus 25 auxiliary indicators for the identification and monitoring of external and internal macroeconomic imbalances, as well as of employment and social developments.

have reinforced divergence across EMU countries, underlining the presence of a core and a periphery subset of countries.

In fact, uneven progress towards achieving the SDGs may be hardening a core-periphery pattern especially in terms of business cycle correlation within the EMU. The heterogeneous redistributive effects of pursuing these 17 goals in individual EMU countries could have potentially exacerbated (or alternatively even mitigated) the pre-existing core-periphery divergence.

Modelling the interaction between Sustainable Development Goals (SDGs) and the business cycle presents a significant challenge, one that current research has not yet started to address. Though Agenda 2030 strives for a balanced and interconnected set of goals, complex synergies and trade-offs exist between them. These intricate relationships make it impossible to define a single, straightforward model of how SDGs interact with the business cycle, necessitating instead a multifaceted approach that accounts for these diverse dynamics. Studies, like those by Singh *et al.* (2022) and Andrianady (2023), are exploring this topic, but they are still in their early stages, and mostly applied to developing countries.

This paper contributes to the existing literature in two ways: assessing i) whether the SDGs might represent themselves a new dimension of the EMU core periphery dualism, and ii) if and how the similarity of the SDG scores for 11 EMU country pairs have been interplaying with the existing dualism in terms of business cycles correlation.

To provide evidence on the first point, we perform a cluster analysis monitoring the progresses towards each of the SDGs. To investigate the second issue, we proceed in two steps: first, we estimate a Panel VAR model and perform Granger causality tests to assess the existence of a causality relationship between business cycle synchronization and convergence in the aggregate SDGs score; second, we calculate Impulse Response Functions (IRFs) to estimate the sign and time profile of the response of each of the two variables to an exogenous shock in the other variable.

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 are presented that test the relationships between SDGs scores convergence and EMU country pairs’ business cycle correlation. Section 4 reports estimations’ results. Conclusions follow.

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

To investigate whether a core-periphery dualism exists within EMU countries regarding progress towards the SDGs, we analysed data and metrics for 11 EMU countries between 2003 and 2021. Specifically, we utilized goal-level scores provided by the Bertelsmann Stiftung and the Sustainable Development Solutions Network (SDSN) (Sachs *et al*. 2022; Lafortune *et al*. 2018).

The 2003-2021 timeframe was chosen for consistency with the rest of the paper, which is limited by data availability. For our analyses, we focused on 11 European countries that were EMU members in 2003: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain. Luxembourg was intentionally excluded due to its unique characteristics.

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[4]. 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-step 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

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

difference between 100 and countries' scores is the distance in percentage that needs to be completed to achieve the goals). A general SDGs score (SDG Index) is also computed, as the arithmetic mean of the 17 SDGs scores.

We classified the 11 countries in the two groups core-periphery by simply applying a clustering procedure (Bacchini *et al.* 2020) to the goals' scores[5] and setting the number of classes to two. In particular, we have performed for each year a standard k-means clustering (MacQueen 1967) on the 16-dimensional vectors containing goal scores, one vector for each country[6]. Since the general SDG Index for each year reaches its maximum for Finland and its minimum for Greece, for each year we can identify two groups, the core group being the one comprising Finland, and the periphery group being the one comprising Greece.

We have checked the robustness of the methodology, both applying a preventive normalization of Goals' scores[7] based only on the set of countries involved (a standard min-max or a standard z-score procedure) and using a k-medians clustering[8] (Jain and Dubes 1988) instead of the more usual k-means clustering. The results are reported in Table 1, as are the number of years (out of 19, from 2003 to 2021) in which a country is classified as core.

We can see that the classification between core and periphery is persistent through time and robust with respect to the adopted methodology. Only for France the classification is uncertain. Results are largely consistent with the existing literature (see Table A1 in the Appendix). In particular, we can identify Austria, Belgium, Finland, Germany, Ireland and the Netherlands as core countries, and Greece, Italy, Portugal and Spain as periphery countries. France occupies an ambiguous position, but since

[5] Goal 14 was not considered, since it is about oceans, seas and marine resources, and Austria (and also other countries used for sensitivity analyses) do not have access to the sea.
[6] We have used the iterative algorithm of the function "kmeans" from the R package "stats", with an increased number of iterations (100) and starting points (1000).
[7] Bertelsmann Stiftung and SDSN's goal scores are already normalized, but with respect to the 193 countries that they consider.
[8] The k-medians strategy minimizes errors with respect to the 1-norm distance metric (Manhattan distance), as opposed to the squared 2-norm (Euclidean) distance metric considered by k-means, usually ensuring a better behaviour in case of outliers. We have used the iterative algorithm of the function "kGmedian" from the R package "Gmedian", with an increased number of iterations (100) and starting points (1000).

the data presented here slightly favours the core classification, for the purposes of this paragraph we will consider France as a core country.

Table 1 – Number of years (0-19) in which a country is classified as core, according to different methodologies. Years 2003-2021.

Country	k-means	min-max + k-means	z-scores + k-means	k-medians
Austria	19	19	19	19
Belgium	19	19	19	19
Finland	19	19	19	19
France	5	18	18	7
Germany	19	19	19	19
Greece	0	0	0	0
Ireland	19	19	19	19
Italy	0	0	0	0
Netherlands	19	19	19	19
Portugal	0	0	0	0
Spain	0	0	0	1

Source: processing of data from Bertelsmann Stiftung and SDSN

We have also considered a k-means clustering approach based on three groups instead of two. In this case, for each year we can identify a top-performing group (the one comprising Finland), a bottom-performing group (the one comprising Greece) but also an “intermediate” group (the remaining group). With respect to this classification, Austria and Germany always belong to the top-performing group; Italy always belongs to the bottom-performing group; Belgium, France, Ireland and the Netherlands in some years belong to the best group, in other years to the intermediate group; Spain and Portugal in some years belong to the worst group, in others to the intermediate group. No country moves between all the three groups over time. This classification is completely coherent with the 2-class core-periphery classification set above, and it gives another reason to prefer a core classification for France.

We also performed some sensitivity analyses on the set of countries subject to the clustering procedure (see Table A2 in the Appendix), and we can conclude that our core-periphery taxonomy is fairly robust and the preferred choice.

In the second part of this section, we stick to the general SDG Index provided by Bertelsmann Stiftung and SDSN to evaluate countries' trends over time, from 2003 and up to 2021, also measuring their convergence within and between the two core-periphery groups just identified.

We opted to evaluate convergence by simply tracking the intertemporal change in the coefficient of variation[9] 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 is extensively used to study the regional/territorial evolution of the main SDGs indicators (for example Marchante *et al.* 2006, Ferrara Nisticò 2013, Simionescu 2014, UNESCAP 2017, Chelli *et al.* 2022, Istat 2021, Istat 2022, Istat 2023).

In Table 2 some descriptive statistics are reported, in order to measure the intra- and inter-dynamics of the two groups. The polarization is evident. Moreover, the dualism has changed considerably in the period 2003-2021, in terms of both relative strengths and distances between main groups of countries but also in terms of the trajectories of individual countries.

On average, peripheral countries saw a greater improvement in their SDG Index compared to core countries during the study period. However, the dispersion of data around the mean (measured by the coefficient of variation, see note 9) reveals a larger reduction for the entire set of countries than for each group individually. These findings suggest both evidence of a core-periphery pattern over the analysed period and a persistent dualism in 2021. Nonetheless, a catch-up process appears to be

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[9] The coefficient of variation at time t is $CV_t = 100 \cdot \frac{\sigma_t}{|\mu_t|} = 100 \cdot \frac{\sqrt{\frac{1}{\#Cou}\sum_{i \in Cou}(x_{i,t}-\mu_t)^2}}{|\mu_t|}$,
where $x_{i,t}$ is the score for country i at time t, μ_t is the mean over i of all $x_{i,t}$'s, and $\sigma_t = \sqrt{\frac{1}{\#Cou}\sum_{i \in Cou}(x_{i,t} - \mu_t)^2}$ is the standard deviation at time t of all $x_{i,t}$'s. Cou is the set of countries under consideration.

underway, with the gap between the two groups nearly halved in the last 18 years (see Table 2).

Table 2 – SDGs as a new dimension of the core-periphery dualism

	2003		2021		Change (%)		Distance Core-Periphery		
	mean	cv	mean	cv	mean	cv	2003	2021	diff (%)
Periphery	72.7	1.4	79.3	1.2	9.2%	-15.7%			
Core	77.1	3.4	81.9	3.0	6.2%	-11.5%	2.96	1.59	-46,4%
Total	75.5	4.1	81.0	3.0	7.3%	-26.9%			

Source: processing of data from Bertelsmann Stiftung and SDSN

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.

3. Empirical test of the relationships between SDGs scores convergence and business cycle correlation

3.1 Econometric strategy and data

To provide evidence on the relationship between macroeconomic imbalances and SDGs scores convergence in the EMU countries we use a Panel VAR (PVAR henceforth) approach (Abrigo and Love 2016; De Santis *et al.* 2021; Guloglu and Tekin 2012; Kacou *et al.* 2022). Given the explorative character of the analysis, the PVAR approach is particularly suitable since it allows one to understand whether there exists a bidirectional relationship between the two variables and how this relationship evolves over time. More specifically, the model is a system of dynamic equations where each variable is expressed as a function of its own lag and of the lags of the other endogenous regressors.

The formal representation of the PVAR model is the following:

$$Y_{(i,j,t)} = BY_{(i,j,t-1)} + E_{(i,j,t)} \quad (1)$$

where B is the vector of equation coefficients; Y is the vector of endogenous variables; and E is the vector of idiosyncratic errors. Subscripts *i* and *j* represent the country pair whereas t is the time dimension.

We estimate two different model specifications: the first one includes a measure of business cycle synchronization (BCS) and a measure of SDGs scores synchronization (SDGS); the second one adds to the first specification measures of trade and financial integration. A large body of empirical research (Clark and van Wincoop 2001; Calderon *et al.* 2007; Kalemli-Ozcan *et al.* 2013a, 2013b; Caporale *et al.* 2014; Oman 2019; Padhan and Prabheesh 2020; Azcona 2022) has shown that bilateral trade and financial flows can affect output synchronization across countries and/or regions.

This leads to the estimation of two different models: Model 1) includes SDGs and BCS and uses the previously defined core-periphery classification; Model 2) adds to Model 1) trade integration measure *(TrInt)* and financial integration (*FinInt*) as endogenous variables.

Given the uncertain classification of France as core or periphery country (see Section 2) and in line with the relevant literature (see Table A1 in the Appendix), as robustness check we replicate the analysis by testing the inclusion of France in the periphery cluster rather than in the core group.

To measure business cycle synchronization, we use the residuals of a regression of growth rates (g) on both countries and year fixed effects (Morgan *et al.* 2004, Caporale *et al.* 2014):

$$BCS_{i,j,t} = -|\gamma_{i,t} - \gamma_{j,t}| \qquad (2)$$

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

Trade and financial integration are measured as the ratio of bilateral trade and financial flows over the sum of country pairs' GDPs. To measure convergence/divergence in SDGs scores we use a similar approach to equation (2), that is the negative of the absolute difference in SDGs scores for country i and country j:

$$SDGS_{i,j,t} = -|SDGS_{i,t} - SDGS_{j,t}| \qquad (3)$$

Accounting for the core-periphery clustering calculated in section 2[10], we estimate the model, alternatively, on the whole sample, on core countries only (core-core), on periphery countries only (periphery-periphery), and on country pairs given by a core and a periphery country (core-periphery).

If imbalances in SDG convergence matter for business cycle synchronization and this effect follows a core-periphery pattern, we would expect different relationships among the two variables across the groups.

More specifically, if the tradeoff between SDGs convergence and output convergence existed, then we would expect this tradeoff to be stronger when considering integration between core and peripheral countries compared to integration within the other two groups.

Since the estimated coefficients form the PVAR model cannot be interpreted as causal effects, we base our analysis on Granger causality tests and on Impulse Response Functions (IRF). The former allows us to understand the direction of (Granger) causality among the variables in the model. The latter allows us to estimate the dynamic response of a variable to an exogenous shock in the other relevant variable. We use the GMM-based test developed by Holtz-Eakin *et al.* (1988), which is valid for homogenous panels with small to mild T.[11]

The explanatory power of our models is assessed by calculating Forecast Error Variance Decompositions. The PVAR model can be estimated consistently only if variables are stationary. While business cycles are stationary by definition, the other variables might have a unit root and, in this event, they have to be introduced in first differences. For this reason, before estimating the models, we perform two unit root tests: the Im, Pesaran and Shin (IPS, 2003) test and the Hadri test. Both have the advantage of controlling for cross sectional dependence, i.e., correlation across panels,

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[10] Core countries include Austria, Belgium, Finland, France, Germany, Ireland and the Netherlands. Periphery countries include Greece, Italy, Portugal and Spain.

[11] When T becomes large, the GMM approach can be weakened by the proliferation of instruments (Xiao *et al.* 2023). In our model, since N is large relative to T the number of instruments (35) is well below the number of panels, thus satisfying the main condition for the GMM estimate of panel data (Roodman 2009).

and can be applied to unbalanced panels.

The sample includes 110 country pairs obtained by combining the 11 EU countries that first adopted the euro in 2002 – excluding Luxemburg - for the period 2003-2021.Data are from different sources. The SDGs indicator is 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 financial flows are from the JRC-ECFIN Finflows database.[12]

4. Results

Tables 3 reports the results of the two unit root tests. The null assumption in the IPS is that data have a unit root, whereas in the Hadri test the null assumption is that data are stationary.

The tests provide the same evidence: *BCS* is stationary whereas *SDGS*, *Trint* and *FinInt* are non-stationary, thus they will be first differenced before estimating the models.

All the estimated PVAR models are stable (see Table A4 in the Appendix) as the Eigenvalues all lie within the unit circle (i.e., their modulus is <1). Granger causality tests are reported in Table 4 and show the existence of a bidirectional causality between *BCS* and *SDGS* both in Model 1) and Model 2). When splitting the sample into the three groups, we can see that bidirectional causality exists for core-periphery and periphery-periphery. In the core-core group instead there is weak evidence of causality from *BCS* to *SDGS* and no evidence of causality from *SDGS* to *BCS*. The same results are confirmed if we include France in the periphery group.

[12] See Table A3 in the Appendix for data summary statistics.

Table 3 – Unit Root Test

	IPS 2003	Hadri
BCS	-10.7***	1.2
SDGs	-0.9	43.1***
TRint	1.3	25.0***
FINint	-13.8***	9.3***

* Significant at 10% level; **significant at 5% level; ***significant at 1% level.

The results seem to provide some evidence that policies aimed at reaching the SDG targets measured by the SDGs scores (i.e., the speed of the progress towards the 17 goals) might have been associated differently with country pairs within the EMU. This evidence alone suggests that the progress towards the Agenda 2030 goals has not been neutral with respect to the core–periphery dualism in the EMU.

Table 4 – Panel VAR-based Granger causality tests

		EMU	core-core	core-periphery	periphery-periphery
Model 1	BSC causes SDGS	20.0***	3.0*	22.4***	11.0***
	SDGs causes BCS	9.2***	2.3	13.0***	4.9**
Model 2	BSC causes SDGS	10.0***	2.7*	8.1***	7.7***
	SDGS causes BCS	16.9***	0.8	16.2***	7.2***

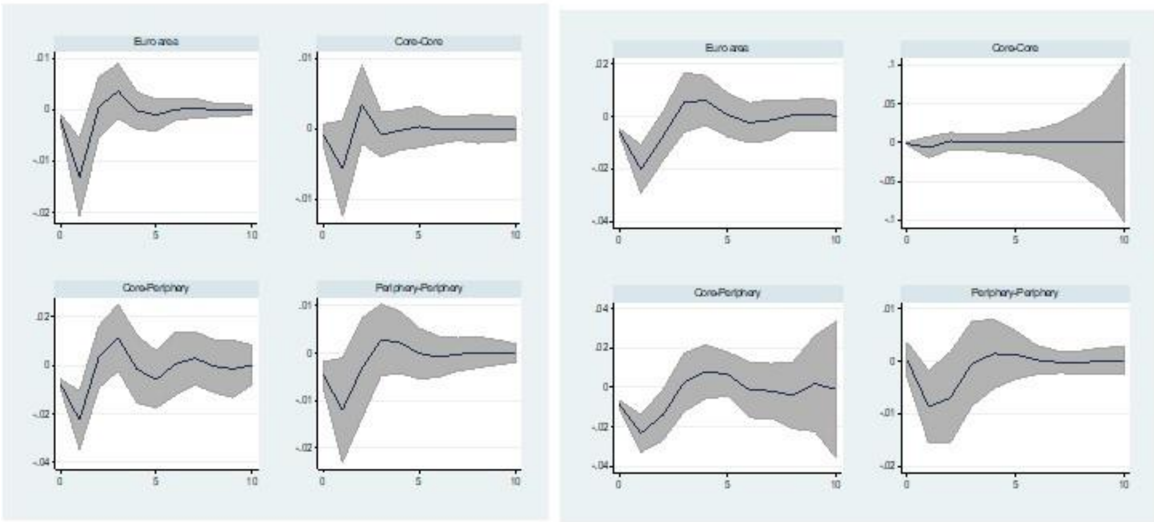
* Significant at 10% level; **significant at 5% level; ***significant at 1% level.

To understand the signs of the relationship between *SDGS* and *BCS* we now move to IRFs analysis. In Figure 1 we report the responses of *BCS* to a shock in *SDGS* for the whole EMU and for the three subgroups and for Models 1 and 2.

The overall effect is negative and increases in the second period while it becomes insignificant from the third period. A similar pattern is found statistically significant for core-periphery pairs and, to lower extent, for periphery-periphery ones. The core-core group also shows a similar pattern; however, the effect is never statistically significant at the 5% level.

Figure 1 – Response of business cycle synchronization to a shock in SDGs scores synchronization (SDGS)

a) Basic model (Model 1) b) Augmented model (Model 2)



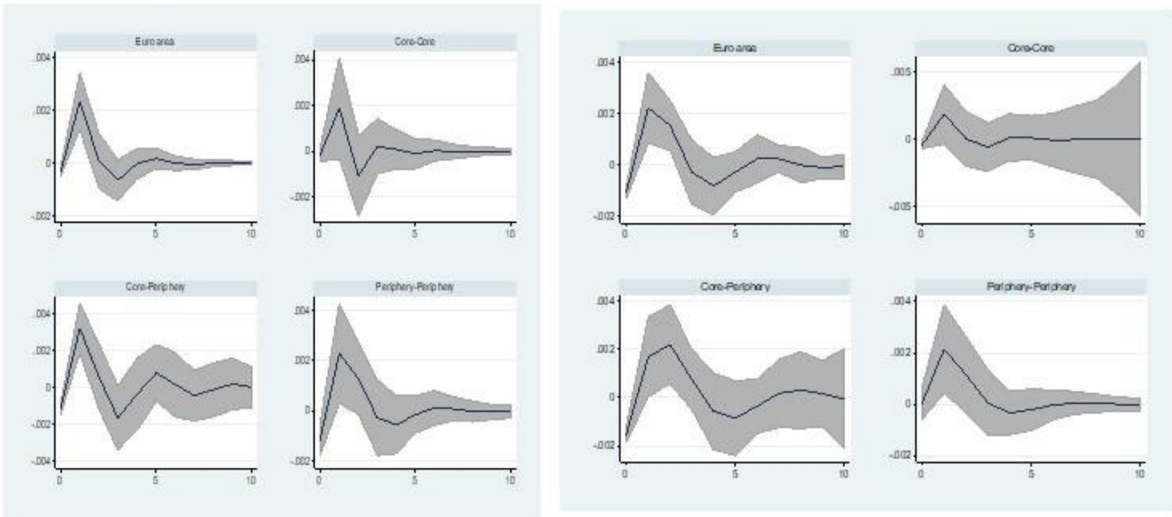
Note: the grey area represents the 95% confidence interval

In Figure 2, we show the response of *SDGS* to a shock in *BCS*. The effect is statistically significant for the whole EMU, for the core-periphery and periphery-periphery pairs, while for core-core pairs the effect is not statistically significant. In all cases, the initial effect is negative but small and then turns largely positive in the second and third periods, leading to a positive cumulative effect.

In Table 5, we show forecast error variance decompositions (FEVDs) calculated after 10 periods. It is worth noticing that for the EMU, each variable explains 23% of the forecast error variance, which increases to 36% for the core-periphery group. In the periphery-periphery group a shock in SDGs scores explains 31% of *BCS's* forecast error variance, while a shock in BCS explain 25% of the *SDGS'* variance.

Figure 2 – Response of SDGs scores synchronization to a shock on business cycle synchronization

a) Basic model (Model 1) b) Augmented model (Model 2)



Note: the grey area represents the 95% confidence interval

Turning to Model 2 (augmented with the first differences of trade and financial integration measures) the results are in line with those of Model 1, the only difference being the higher variance at the end of the forecasting period in the case of the response of *BCS* to a shock in *SDGS*. The introduction of the measures of economic integration, however, changes the explanatory power of our main variables. As shown in Table 5, the forecast error variance of *BCS* explained by *SDGS* increases to 39% for the whole EMU, while it falls to 19% for the periphery-periphery group.

Figures A1 and A2 in the Appendix (as robustness check) show the results by group with France classified as periphery country. The previous results are broadly confirmed, although the variance of IRFs increases. This increase means that the explanatory power of the model is higher when France is classified as core country, confirming our initial definition of clusters.

Table 5 – Forecast error variance decomposition

		FEVD	
		SDGS on BCS	BCS on SDGS
Model 1	EMU	0.23	0.23
	Core-Core	0.08	0.22
	Core-Periphery	0.37	0.36
	Periphery-Periphery	0.31	0.25
Model 2	EMU	0.23	0.23
	Core-Core	0.19	0.36
	Core-Periphery	0.27	0.29
	Periphery-Periphery	0.31	0.22

Source: our own elaborations

5. Conclusions

In this paper we investigated whether the core–periphery dualism of EMU members has been somehow related to the process to meet the Agenda 2030 SDGs and if the latter themselves can be shaped as a new dimension of the dualism.

Our main results can be summarized as follows. First, the cluster analysis evidenced that there was a core-periphery pattern for SDGs scores in the period 2003-2021 for 11 EMU countries, although the distance between and within the two groups has been diminishing overtime.

In this respect, the fact that the core-periphery dualism related to a broad group of economic, social and environmental indicators (SDG targets) has been diminishing over time as predicted by the endogeneity theory of Frankel and Rose (1985) is comforting: it should have enhanced the effectiveness of the common European policies over time. The convergence process, however, seems to be very slow since the dualism persists more than two decades after the creation of the currency area.

Second, we provide evidence of a bidirectional Granger causality between the convergence of SDGs and that of business cycles. Third, we find that, for EMU member pairs which are in the periphery group or between the core-periphery country pairs, the convergence in SDGs scores causes a divergence in business cycles while business cycle convergence causes a convergence in SDGs scores. This pattern is not statistically significant for core country pairs, suggesting that, as previously noted in the literature, initial differences (like stronger business cycle correlation in the core countries) play a role.

This evidence suggests that the common European policies, although strongly committed to the 2030 Agenda, should be tailored also to contain asymmetric shocks and to favour business cycle correlation among EMU countries. The latter seems to be not only a necessary pre-condition for an effective one-size-fits-all monetary policy and coordinated fiscal policies, but also an incentive to speed up the reaching of the SDG targets, "leaving no one behind".

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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 **Intermediat**e: the 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, the 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.

Table A2 – Number of years (0-19) in which a country is classified as Core, according to different set of countries. Years 2003-2021.

Country	EMU03-noLux	EMU03	EMU21	EMU21+
Austria	19	19	19	19
Belgium	19	19	19	19
Finland	19	19	19	19
France	5	4	19	19
Germany	19	19	19	19
Greece	0	0	0	0
Ireland	19	19	19	17
Italy	0	0	0	0
Netherlands	19	19	19	19
Portugal	0	0	0	0
Spain	0	0	2	0

Source: processing of data from Bertelsmann Stiftung and SDSN

Note: k-means clustering based on four different sets of countries: EMU03-noLux are EMU countries in 2003, excluding Luxembourg (11 countries); EMU03 are EMU countries in 2003, including Luxembourg (12 countries); EMU21 are EMU countries in 2021 (19 countries); EMU21+ are EMU countries in 2021 plus United Kingdom, Norway and Switzerland (22 countries).

Table A3 – Data source and descriptive statistics

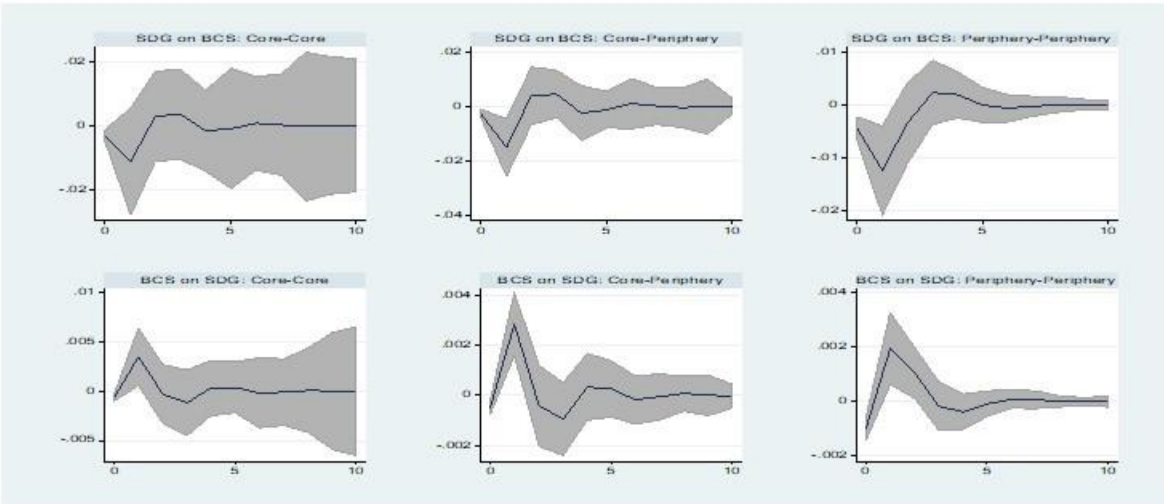
	Mean	SD	Min	Max
BCS1	-0.01673	0.020445	-0.09799	0
BCS2	-0.02003	0.025788	-0.17842	0
TRint	0.016134	0.021999	0.000572	0.219785
FDIint	0.013944	0.063897	-0.6511	0.575059
PTFint	0.012176	0.053596	-0.26258	0.466121
SDG	-0.034	0.026912	-0.13285	0

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

Table A4 – PVAR stability conditions

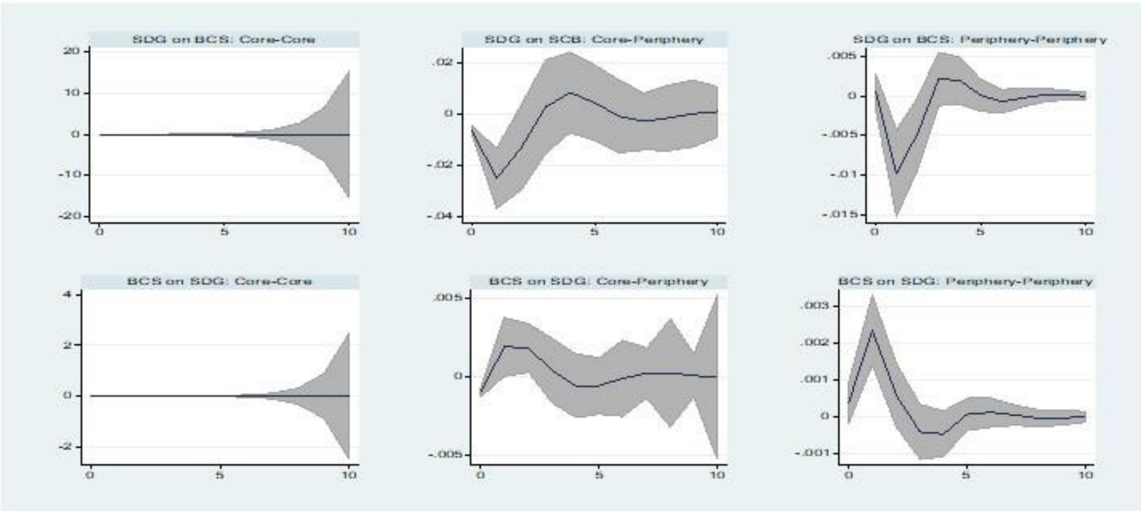
		Eigenvalues moduli	
		1	2
Model 1	EMU	0.52	0.52
	Core-Core	0.45	0.45
	Core-Periphery	0.71	0.71
	Periphery-Periphery	0.58	0.58
Model 2	EMU	0.52	0.52
	Core-Core	0.59	0.59
	Core-Periphery	0.6	0.6
	Periphery-Periphery	0.55	0.55

Figure A1 – Impulse response functions: Core-periphery classification 2, baseline model



Note: the grey area represents the 95% confidence interval

Figure A2 – Impulse response functions: Core-periphery classification 2, augmented model



Note: the grey area represents the 95% confidence interval