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Deep Ranking Analysis by Power Eigenvectors (DRAPE): Linking Sustainability and National Competitiveness

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Abstract

There has been limited research on integrating sustainability factors into indicators of global competitiveness among nations. Extant measures of macroeconomic competitiveness focus inadequate attention on the relative importance and interdependences among economic, social, and environmental factors and often their aggregation method. The primary objectives of this study were to explore the interrelations of economic competitiveness and sustainability while integrating the economic and sustainability performance indicators of the Global Competitiveness Index (GCI) and the Global Sustainable Competitiveness Index (GSCI) to create more accurate rankings of countries in both dimensions. Deep Ranking Analysis by Power Eigenvectors (DRAPE) with Variable Clustering (VARCLUS) was applied to associate multiple and conflicting economic and sustainable competitiveness criteria. Consequently, economic competitiveness and mainly institutional environment and innovation capabilities tend to couple with a higher degree of sustainability. However, improving and refining sustainable competitiveness may be vulnerable to environmental issues and resource scarcity, but further socio-economic dimensions must also be considered. The outcomes demonstrate the leadership of the Scandinavian countries and Switzerland, which are all competitive as well as sustainable. This research may extend and inspire further studies and government interventions that adopt more comprehensive approaches to assessing global competitiveness.

Keywords: cross-country comparison, deep ranking analysis, clustering method, global and sustainable competitiveness
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1. INTRODUCTION

It is widely accepted that prioritising the economic aspect of human life and continuous development leads to adverse and unfavourable side effects. For example, the environmental impacts of economic growth create an increase in real output, leading to higher pollution (Balogh

& Jámbor, 2017), increased consumption of non-renewable and scarce resources (Namany et al., 2019) as well as global warming and potential loss of environmental territories (Popescu et al., 2017).

The more pragmatic goal of international competitiveness is to elevate living standards along with fair and equitable distribution by employing them efficiently, without abating the economic growth potential of future generations (Utama et al., 2018). Integrating national competitiveness with sustainability has presented numerous challenges for researchers and policymakers. A significant issue associated with understanding and achieving "sustainable competitiveness" is that its complexity should be reflected in the proposed measurement concepts. Cheba et al. (2020) considered a general perception of achieving a sustainable competitive environment and position as a share of the state and the economy in the context of broad international turnover. Another research problem concerns significant spatial and temporal differences in determinants of competitiveness (Porter & Rivkin, 2012). Not surprisingly, different interpretations based on various competitiveness indicators and rankings lead to diverse results. However, the most transparent way to determine the competitiveness positions of nations is to utilise composite indices.

Most of the previous studies in the competitive analysis have focused only on the construction of composite indicators linked to the dilemma of selecting appropriate variables. Only a few quantitative analyses adequately addressed the relative importance of weights and the aggregation selection method of competitiveness pillars. This study aims to examine countries' global and sustainable competitiveness rankings to garner novel insights into the formulation and promotion of future competitiveness policies. The novelty of this approach is that two groups of complex competitiveness indicators are considered simultaneously as criteria predicated on mathematical methods. Thus, this research seeks to assess the influence of each criterion on the final competitiveness ranking by weighting simultaneously. Data from the study were collected from 2019 by combining GCI and GSCI databases. Deep Ranking Analysis by Power Eigenvectors (DRAPE) was utilised to calculate the ranking of the indicators within the country group and their competitive level, thereby determining the most competitive countries based on power weakness ratios (PWRs). In addition, the advantage of the VARCLUS clustering approach is to develop a more accurate assessment of countries consistent with its stages of development. In Section 2, the literature on competitiveness rankings is discussed; Section 3 presents the variables and methodology; Section 4 includes the results and their discussion, and the paper concludes in Section 5 with suggestions and limitations. Our findings provide a significant contribution to the ranking of countries while also considering competitiveness in terms of both global and sustainable positions.

2. THEORETICAL BACKGROUND

Competitiveness can be studied at the level of a firm, region, and nation; however, in this paper, we also concentrate on the national level. Whilst Krugman (1994) considers that studying national competitiveness is meaningless, wrong, and dangerous, a large and growing body of literature has investigated the concept of national competitiveness. Moreover, due to the lack of generally

accepted concepts, researchers have proposed numerous approaches to estimate competitiveness. The evolution of this argument has conventionally revolved around aspects such as the division of labour and specialisation, market share, costs and prices, and productivity (income per capita). Firstly, Adam Smith and David Ricardo attempted to clarify competitiveness stemming from the traditional trade theory (i.e., absolute and comparative advantage); next, Heckscher and Ohlin derived comparative advantage from the relative abundance or scarcity of production (Siudek & Zawojska, 2014). Although comparative advantage has remained the mainstream idea for international trade, Cheba et al. (2020) recognised it as an incomplete explanation regarding the competitive advantages experienced within the modern business environment. As a result of trade liberalisation, endowed resources can be transferred across countries. Hence, these aspects are unlikely to adequately determine national competitiveness in a holistic context.

Moreover, Michael Porter introduced a significantly different approach in the 1990s. In the diamond model, Porter (1990) listed several crucial factors that define a country's competitiveness: factor and demand conditions; supporting industries; firm strategy; structure and rivalry; chance; and government. However, as all countries have comparative and competitive advantages, there is no consensus concerning which global economic or social factors can be applied to define competitiveness universally. For example, competitiveness is claimed to be affected by various institutions such as public authorities, trade unions, financial and socio-political organisations, and property rights, including customs and rules of conduct (Holcombe, 2021).

More approaches relate competitiveness to sustainability and living standards. Competitiveness is explained as the sustainable growth involving the living standards of the whole population in each country (Thore & Tarverdyan, 2016). Nonetheless, living standards are often measured by output (GDP) per worker or per working hours and denote potential productivity (Haseeb et al., 2019; Meyer & Meyer, 2017). Productivity growth has been considered a significant determinant of competitiveness which requires a business environment that supports continuous innovation in products, processes, and management. Krugman's theory of economic geography demonstrated the relevance of productivity as the primary driver of competitiveness, where the international competitiveness of countries is linked to their high standard of living (Krugman, 1996).

Additionally, competitiveness is interpreted by Zmuda (2020) as a nation's ability to reach developmental goals in the era of globalisation. Zmuda further suggested supplementing GDP per capita with socio-ecological measures. However, GDP has long been criticised as an overall metric for wellbeing. Scholars developed alternative performance indicators (e.g., Index of Sustainable Economic Welfare and Genuine Progress Indicator) to incorporate environmental, social, and economic information (Meyer et al., 2017). Sustainable development has been defined as the needs of the present without compromising the ability of future generations to meet their own needs (Barbier & Burgess, 2019). However, there seems to be an insoluble conflict between economic, social, and environmental development. Hence, competitiveness concepts have been given increasing attention to achieve the integration of sustainability approaches, which have been interpreted rather loosely from "greenness" to continuously improving quality of life (Dobrovic et al., 2018).

According to Aiginger & Firgo (2013), sustainable competitiveness is an aptitude to generate and maintain wellbeing and a decent standard of living for all citizens without reducing future ability.

Corrigan et al. (2014) indicated sustainable competitiveness as a set of institutions, policies, and factors that make a nation productive in the long run while ensuring social and environmental sustainability. "Smartness" (smart growth and smart cities) is an initiative that combines local and global aspects and (growth-oriented) competitiveness and sustainability considerations (Bibri, 2019). Esty (2021) proposed imperatives to explain why environmental performance correlates with national competitiveness: eco-efficient technologies that (1) reduce waste and are also more energy efficient; (2) produce eco-friendly products, production techniques, and services that reduce environmental impacts and resource consumption; (3) create novel product categories and even new industries; and (4) improve human health.

Over the past few decades, there has been a growing academic debate about better pathways to define and measure national competitiveness (Kiselakova et al., 2020). Advances in information and communications technologies (ICTs) and the R&D intensity of products and services, as well as environmental challenges and resource scarcity, have provided new opportunities and new constraints for improving competitiveness in an increasingly complex globalised economy (Sima et al., 2020). Notwithstanding, the obsession with ranking countries in a "league table" led to several systems of competitiveness indicators over the years. There are more than one hundred composite indices that measure national performance. However, no theory or general conceptual framework guides the selection and aggregation of such collections of diverse variables. These rankings often rely merely on the economic aspects of wellbeing. They are based on snapshots over time (Bergsteiner & Avery, 2019) without considering the impact of recent economic activities on future development and wealth capabilities. Furthermore, focusing on economic and financial performance assumes that the physical (natural) environment is not essential for the standard of living. There is a general lack of high-quality, internationally comparable data on social and environmental sustainability that would allow countries to evaluate and benchmark themselves against peers to identify and implement appropriate policies that would lead to desired outcomes (Stiglitz et al., 2009)

The most popular competitiveness rankings nowadays, the World Competitiveness Yearbook (WCY) and the Global Competitiveness Index (GCI), are both published in Switzerland by the International Institute for Management Development (IMD) and the World Economic Forum (WEF), respectively. The WCY benchmarks the performance of 64 countries (2021) based on 334 competitiveness criteria (27.5% are survey data). This ranking relies on four competitiveness factors: (1) economic performance, (2) government efficiency, (3) business efficiency, and (4) infrastructure. Each factor is broken down into five sub-factors, including a different number of single variables, which are first aggregated on the level of the sub-factor, and then on the level of the significant competitiveness factor to form the overall score as a percentage of the highest score. IMD defines competitiveness as "the extent to which a country fosters an environment where enterprises can achieve sustainable growth, generate jobs and, ultimately, increase welfare for its citizens" (IMD, 2019). Countries' performance on all the (17) Sustainable Development Goals (SDGs) is crammed into one single variable (within the "Institutional framework" sub-factor of "Government efficiency"). SDGs are required efforts of the United Nations (UN) to promote policies and approaches that can encompass several aspects of the wellbeing of humanity and ensure the future of the planet (Allen et al., 2016). However, the "Health and environment"

sub-factor within "Infrastructure" contains numerous SDG-related criteria. As such, there seem to be both overlaps of factors and inconsistent weighing of sustainability-related variables across factors.

In 1996, the WEF began publishing its ranking (Global Competitiveness Report) and changed the methodology constantly until the Global Competitiveness Index was introduced in 2004. The ongoing reports aim to understand the main drivers of economic growth and explain why some countries raise their income levels more effectively than others (Simionescu et al., 2017). It also offers a tool for formulating better economic policies and institutional reforms (Vianna & Mollick, 2018). The GCI ranked 141 countries in 2019 based on 113 variables, more than two-thirds represent primary data based on business executives' opinions and perceptions. It is built on twelve pillars that consist of three sub-indices: (1) basic requirements, (2) efficiency enhancers, and (3) innovation factors. Based on a given country's development stage, the combination of the three sub-indices is weighted differently. For example, the weight of "basic requirements" is the highest for less developed (factor-driven) countries and the smallest for "innovation-driven" economies (World Economic Forum, 2019). The WEF defines competitiveness "as the set of institutions, policies, and factors that determine the level of productivity of a country" (Sala-I-Martin et al., 2008). Sustainability, especially in earlier reports, refers to sustaining high levels of income, wages, productivity, and growth. The 2019 competitiveness report emphasises that environmental, social and economic agendas "must be merged into a single sustainable and inclusive growth agenda" (Schwab, 2019).

The WEF introduced two additional but separate pillars based on the premise that competitiveness is necessary but not sufficient for sustained wellbeing (Corrigan et al., 2014). These two pillars are social sustainability (access to necessities, vulnerability to economic exclusion and social cohesion) and environmental sustainability (environmental policy, usage of renewable resources, and degradation of environment). The sustainability pillars are used to generate three additional indicators: Social Sustainability-adjusted GCI, Environmental Sustainability-adjusted GCI, and Sustainability-adjusted GCI (combining the former two). The WEF admits that their method lacks a flawless theoretical strategy and, for simplicity, each indicator has been given equal weight within each pillar. The main limitation of this approach is that it allows for some compensation across the various sustainability dimensions; hence, the overall score may mask an uneven performance across different competitiveness dimensions (Kiselakova et al., 2018).

Nevertheless, the sustainability-adjusted GCI is essential to rank countries and universal (social, economic, and environmental) values and measure actual living standards. However, the adjusted GCI framework is based on executive opinion, which involves individual (e.g., leadership) perceptions, and generally, most indicators focus on the policy and regulatory levels. Rankings show that more competitive countries also tend to perform better in sustainability, chiefly social sustainability (Bergsteiner & Avery, 2019). Not surprisingly, in countries with more mature institutions and policies, people have improved access to basic infrastructure, healthcare, and wellbeing. However, the results are more complicated and misleading regarding the natural environment. It would appear that the less developed countries perform better in specific sustainability dimensions (e.g., manufacturing-related pollution and waste) and worse in others (e.g., damage resulting from the expansion of agriculture and rapid urbanisation) (World Economic Forum, 2019).

Overall, developing a universally-accepted model measuring international competitiveness with sustainable economic growth has been challenging. The Global Sustainable Competitiveness Index (GSCI), developed by SolAbility Sustainable Intelligence (SolAbility, 2019), is, therefore, quite an innovative candidate. The organisation defines sustainable competitiveness as "the ability of a country to meet the need and basic requirements of current generations while sustaining or growing the national and individual wealth without depleting natural and social capital" (Gebhardt & Hyang Lee, 2013). The GSCI measures countries' current and future capability to generate and sustain financial and non-financial income and wealth for the people. The index is calculated based on (127) quantitative performance indices, grouped in the five sustainability pillars (e.g., natural capital, resource efficiency and intensity, intellectual capital, governance efficiency and social cohesion), weighted equally and not aggregated as in the GCI. However, the economic indicators do not reflect the real or perceived wealth of the average citizen. According to SolAbility's latest GSCI report (SolAbility, 2021), the most sustainably competitive nations are high-income countries. Meanwhile, some emerging countries scored much better in the GSCI than their per capita income (GDP), while some resource-rich economies underperformed concerning sustainability.

3. DESIGN AND METHODS

The study explores how measuring competitiveness and ranking countries vary according to the global economic and sustainable concepts applied, using specific social and economic indicators and mathematical methods. The research seeks to address how competitiveness indicators relate to particular groups of countries.

This paper carefully selected global and sustainable competitiveness variables. Data were collected from 2019 using a complete combination of the GCI and GSCI databases based on the available releases. A cross-country comparative framework (the year 2019) was established to analyse the global and sustainable competitiveness ranks of 139 UN countries (see Appendix) after merging the two databases. GCI (4.0) was provided by WEF, while an updated GSCI was retrieved from SolAbility. The GCI comprises twelve competitiveness pillars, while the GSCI has five sub-indices. Table 1 depicts each of the indices (dimensions), respectively (their descriptions have been taken entirely from the two databases).

Tab. 1 – Selected global and sustainable competitiveness variables. Source: SolAbility (2019); The World Bank (2019)

Source	Variable	Description
GCI	Institutions	The institutional environment is defined by the legal and administrative framework within which individuals, companies and governments interact to create prosperity.
	Infrastructure	Extensive infrastructure ensures the efficient functioning of the economy by determining the location of economic activity and sectors that may develop within a country.

GCI	ICT adoption	The degree of dissemination of specific information and communication technologies (ICTs).
	Macroeconomic stability	The stability of the macroeconomic environment is essential for businesses when their public debt has reached unsustainable levels in the wake of a global financial crisis.
	Health	A healthy workforce is vital to a country's competitiveness and productivity.
	Skills	Quality higher education and training are essential for economies that want to move up the value chain beyond simple manufacturing processes and products.
	Product market	Countries with efficient goods markets are well placed to produce the right mix of products and services, given their specific market situation.
	Labour market	Labour market flexibility is critical to ensure that workers are assigned to the economy and given incentives to do their best in their work.
	Financial system	The financial and economic crisis has highlighted the central role of a sound and well-functioning financial sector in economic activities.
	Market size	The size of the market affects productivity because large markets allow companies to take advantage of economies of scale.
	Business dynamism	Business practices are conducive to higher efficiency in producing goods and services.
	Innovation capability	Innovation capability helps achieve a higher competitiveness performance and advance the process towards structural changes.
GSCI	Natural Capital	Natural capital encompasses a particular natural environment, including the availability and the extent to which those resources are depleted.
	Social capital	Health, security, freedom, equality and life satisfaction within the country.
	Intellectual capital	Intellectual capital is a potential for prosperity and job creation through innovation and value-added industries in globalised markets.
	Governance Efficiency	The results of core public areas and investments are infrastructure, market and employment structure, and a framework for sustainable wealth production.
	Resource Management	Resource management means efficiency in using available resources to measure operational competitiveness in a resource-constrained world.

The WEF (World Economic Forum, 2019) classifies economies by their economic development level (stages). Factor-driven economies (Stage 1) are dominated by subsistence agriculture and

extractive firms and rely heavily on unskilled labour and natural resources. However, efficiency-driven economies (Stage 2) have even more competitive and efficient production processes and increased product quality. Additionally, innovation-driven economies (Stage 3) are more knowledge-intensive with expanding service sectors. It should be noted that transitions between stage 1 to 2 and stage 2 to 3 continue to exist. These transitional categories include specific countries, such as Azerbaijan, Botswana, Honduras, Nigeria, Ukraine, Venezuela and Vietnam (1 to 2) and, i.e., Argentina, Chile, Hungary, Malaysia, Saudi Arabia, Turkey and Uruguay (2 to 3), which do not fall into any of the three (driven) categories mentioned above.

Ranking and multi-criteria decision-making approaches (MCDAs) are valuable tools to analyse multivariate data and provide beneficial insights into the data structure and relationships between samples and variables (Kumar et al., 2017). Todeschini et al. (2019) proposed a novel ranking method called Deep Ranking Analysis by Power Eigenvectors (DRAPE), which conducts a power-weakness ratio analysis that provides a set of sequential rankings. The sequential ranking procedure provides deeper insight into the analysed data set, and the method is based on calculating the power-weakness ratio (PWR) from the tournament matrices as proposed by Kendall (1955).

The tournament matrix includes the pairwise comparisons of all countries. The matrix entries are values (also called thresholds) between 0 and 1, which show how many times a country is better for all criteria examined than another country. The closer the value is to one, the higher the probability of the object winning. The tournament matrix is decomposed into eigenvalues and eigenvectors. The eigenvector represents the best representation of the tournament matrix, while the eigenvalues are the explained variances (Tobiszewski & Orlowski, 2015). The first eigenvector reveals the power of an object (country) that has won over the others, and the second one represents the weakness when the others defeat the country. PWR denotes the ratio of these eigenvectors.

The next step is to study the ranking and improve its quality; thus, it is necessary to smooth the original tournament matrix (Cassotti et al., 2016). For this purpose, a family of threshold values (t*) was obtained from the basic matrix by selecting all the different values greater than 0.5. Next, all the entries in the matrix within the interval [1-t*, t*] were minimised to 0.5. Different PWR values can be calculated from these modified tournament matrices. Finally, the consensus of the PWR-based rankings was calculated by a Principle Components Analysis (PCA) that corresponds to an optimal threshold value. Another advantage of the method is that it offers a posteriori variable importance perception by correlating all criteria to the PWR ranking.

The DRAPE method was implemented using the authors' source code in R-Project 3.4.4 (R Core Team, 2020). In our empirical research, the DRAPE method was utilised to rank countries according to global and sustainable competitiveness indicators (GCI and GSCI) and a combination of both. Overall, DRAPE can decisively determine which countries will prevail (with higher competitiveness indicators) compared to previous approaches.

Furthermore, it is more challenging to identify irrelevant inputs than redundant ones (Danasingh et al., 2020). An appropriate strategy is first to reduce redundancy and overcome irrelevance in a lower-dimensional space. Variable clustering (VARCLUS) is closely related to principal

component analysis and can be employed as an alternative method to eliminate redundant dimensions. Additionally, the VARCLUS procedure can rapidly reduce the number of variables used to build the segmentation model. This method detects groups of variables that correlate as closely as possible, providing they do not correlate with variables in other clusters. Vigneau & Qannari (2003) claimed that the clustering of variables around latent components is used to organise multivariate data into meaningful ranking structures. The interest objectives are a clustering of variables around latent components expressed as linear combinations of external variables and how different clusters may be interpreted in these redundant external data.

The procedure first employs a hierarchical (agglomerative) cluster analysis for an initial grouping; then latent components are assigned to each cluster. In the last step, new clusters are formed based on the squared Pearson correlation coefficient (r2) between the variables and the latent component. The procedure is iterative and stops when the cluster structure is stable. The aggregation strategy is based on variances but not the same as in the Ward minimum variance strategy. The merging of two clusters is based on the minimum decrease of all the explained variance after the aggregation. One of the major advantages of VARCLUS over a simple PCA is that the obtained structure is different and may be easier to interpret.

4. RESULTS AND DISCUSSION

The differences between the groups of countries are shown in Table 2. The groups of countries follow the increasing value of the power weakness ratio (PWR) indicator. Not surprisingly, based on the rising mean of the PWR, it can be seen that economically developed countries are also more competitive when estimated by group stages.

Tab. 2 – Descriptive statistics and PWR by group stages. Source: own research

Groups	Mean PWR	N	S.D.
Stage 1	0.392	33	0.202
Transition from 1 to 2	0.773	14	0.314
Stage 2	0.922	31	0.386
Transition from 2 to 3	1.476	20	0.599
Stage 3	4.771	34	2.947
Total	1.783	139	2.281

Notes: N – number of countries, S.D. – standard deviation.

The differences in group means were analysed by using the F-test, which is reliable for many alternative distributions. The higher the F-statistic, the larger the dispersion between groups for a given indicator. According to the results (Table 3) of the analysis of variance (ANOVA), each competitiveness pillar has significant F-statistics at the 0.001 p-level and varies significantly across country groups, except for natural capital (F=1.39). In other words, the natural resources pillar is not aligned with the PWR scores and the importance of competitiveness rankings. The Pearson's correlation coefficient (r) measures the strength of the linear relationship between the indicators and the PWR scores. Based on Pearson's coefficient and ANOVA F-statistic,

Innovation capacity (Pillar 12) is the most significant competitiveness factor, followed by Institutions (Pillar 1). Financial system (Pillar 9) and Skills (Pillar 6) have relatively higher correlations with the PWRs than the other competitiveness indicators. Resource intensity (Pillar 17) and Market size (Pillar 10) have a minor influence on the PWRs.

Tab. 3 – Ranking of competitiveness indicators by blocks. Source: SolAbility (2019); The World Bank (2019)

Blocks	Indicators	Pearson PWR	Ranking by PWR	Ranks within block	ANOVA F	Ranking by ANOVA
GCI	1. Institutions	0.777	2	2	54.23*	4
	2. Infrastructure	0.657	9	7	82.98*	1
	3. ICT adoption	0.639	10	8	53.95*	5
	4. Macroeconomic stability	0.573	12	10	17.7*	14
	5. Health	0.557	13	11	52.74*	6
	6. Skills	0.699	5	4	76.83*	3
	7. Product market	0.636	11	9	36.22*	9
	8. Labour market	0.698	6	5	25.02*	12
	9. Financial system	0.724	3	3	39.51*	8
	10. Market size	0.379	15	12	7.33*	15
	11. Business dynamism	0.671	8	6	28.42*	10
	12. Innovation capability	0.841	1	1	82.47*	2
GSCI	13. Natural capital	0.115	17	5	1.39	17
	14. Social capital	0.675	7	2	20.96*	13
	15. Intellectual capital	0.702	4	1	50.38*	7
	16. Governance efficiency	0.517	14	3	27.84*	11
	17. Resource intensity	0.217	16	4	6.43*	16

Notes: *: significant at 0.001 ($p<0.001$)

A new single ranking that reflects both global and sustainable competitiveness is, therefore, required. Table 4 shows the optimal thresholds calculated from the tournament tables, ranking the final competitiveness. All threshold values are around 0.7, indicating that a country is considered dominant in the tournament matrix if it scores better in 70% of the criteria. It also means that if one country is better (winner) than another, it is more competitive. Table 4 lists the

top ten countries according to the GCI and GSCI, respectively, and considers the two groups of indicators together. It was determined that four countries ranked high in both rankings: Switzerland, Sweden, Finland, and Denmark. Switzerland has a high position and leads in both, while Scandinavia is also constantly at the forefront. The Appendix contains the full list of ranked countries.

Tab. 4 – Ranking of competitiveness indicators by (top ten) countries. Source: SolAbility (2019); The World Bank (2019)

GCI		GSCI		Both	
Country	PWR	Country	PWR	Country	PWR
Singapore	17.69	Finland	15.18	Switzerland	11.28
Holland	14.13	Sweden	9.86	Sweden	10.67
Switzerland	12.69	Iceland	8.00	Finland	10.33
Sweden	12.28	Denmark	6.98	Denmark	9.32
Japan	11.59	Switzerland	6.19	UK	6.45
UK	11.24	Luxembourg	4.4	Germany	6.39
Denmark	10.04	Lithuania	4.35	Japan	5.7
Germany	9.52	Croatia	4.31	Holland	5.67
USA	9.28	Estonia	4.16	Norway	5.16
Finland	8.18	New-Zealand	3.98	Luxembourg	5.22
Optimal threshold	0.708		0.700		0.676

In addition, the GCI rankings are led by Asian and Northern European countries, indicating that the outcome of economic growth is coupled with a national social consensus. Asian nations (i.e., Singapore and Japan) lead intellectual capital as the basis for innovation. However, low natural capital constraints and resource efficiency may jeopardise achieving sustainable prosperity in these countries. Also, the GCI ratings do not consider the underlying sustainability factors and only describe the symptoms, not the causes. Finland and Sweden lead the GSCI rankings, followed by Denmark and Iceland. It is evident that the top ten are dominated by northern European countries, including the Baltic States, with only one non-European (New Zealand) country that made it to the rankings. In the combined (both) rankings, most EU-15 countries have the highest positive correlation with the PWRs when associated with global and sustainable competitiveness.

The research results confirm differences in the groups of countries regarding the level of sustainable development achieved. Cheba & Szopik-Depczyńska (2019) presented similar results after assessing the competitiveness of European Union (EU) countries: nations in Northern and Western Europe perform better in terms of economic and sustainable competitiveness compared to Eastern and Southern Europe.

The VARCLUS method was applied to determine the clusters of the most relevant indicators and to study the relationships between the two composite competitiveness index (pillar) groups. In our case, clustering competitiveness indices were more practical because VARCLUS can select the most correlated composite measures from both groups and create subsequent subgroups.

The initial cluster was divided into three clusters containing two, eight, and seven indicators.

Figure 1 shows these competitiveness clusters, where the first one separates Natural capital and Resource intensity. Sustainable Social capital, Intellectual capital and Governance efficiency indices were included in the Infrastructure, ICT adoption, Skills, Health and Market size of the GCI. As can be ascertained, the explanatory power in the clusters is high. The proportions explained in each cluster are 67.2%, 74.1% and 80.5%; overall, the latent components explain 76% of the variance.

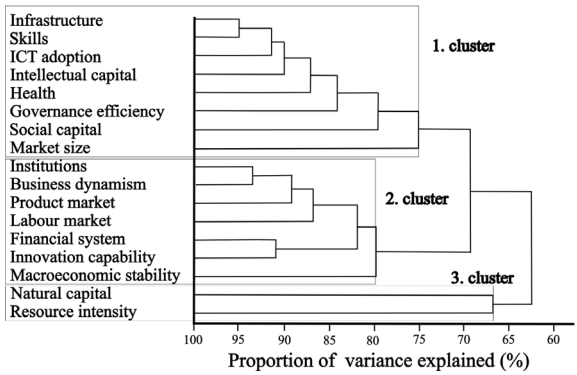

Fig. 1 – Agglomerative clustering of competitiveness indicators (left axis) and Pearson correlation coefficients (right axis). Source: own research

Table 5 will reflect the number of the final (three) indicator clusters created by VARCLUS. This method also highlights which variables have been assigned to the three clusters. The Pearson r2 measure practically indicates how well the variables in each cluster correlate with the cluster's latent component. The indicators are selected into a given cluster so that they have a high correlation with their own cluster $r^2_{(OWN)}$ and a lower correlation with the closest clusters $r^2_{(CLOSEST)}$. The 1-r^2 ratio is calculated as follows (SAS Institute Inc, 2013):

$$1 - r^2\ ratio = \frac{1 - Pearson\ r^2_{(OWN)}}{1 - Pearson\ r^2_{(CLOSEST)}} \quad (1)$$

In the best-case scenario, a given indicator is strongly correlated to its cluster ($r^2_{(OWN)} \rightarrow 1$) and uncorrelated to the closest cluster ($r^2_{(CLOSEST)} \rightarrow 0$), therefore, the 1-$r^2$ ratio is close to 0 (Sanche & Lonergan, 2006). Hence an indicator with the lowest 1-r^2 is likely to be the best representative for the cluster. These include indicators such as natural capital, infrastructure, and institutions, which are listed in the order in which the cluster appears.

Based on the results of the VARCLUS clustering, three synthetic components (PC) were created according to the given indicator clusters. Therefore, each component represents a particular cluster of indicators with a single value. These components are different and easier to interpret than the rotated principal components, and this is the main advantage of using the VARCLUS method. This case study implies that several competitiveness criteria can be combined into a single qualitative ranking, and the DRAPE method allows the ranking to be customised using different weighting schemes.

Tab. 5 – Correlations of variables to their own and next closest clusters. Source: SolAbility (2019); The World Bank (2019)

Clusters	Indicators	$r^2_{(OWN)}$	$r^2_{(CLOSEST)}$	1-r^2 ratio*
1	Natural capital	0.672	0.009	0.331
	Resource intensity	0.672	0.018	0.334
2	Infrastructure	0.919	0.733	0.305
	Skills	0.867	0.699	0.442
	ICT adoption	0.840	0.649	0.456
	Intellectual capital	0.851	0.614	0.386
	Health	0.767	0.463	0.435
	Governance efficiency	0.738	0.483	0.507
	Social capital	0.622	0.451	0.689
	Market size	0.318	0.215	0.870
3	Institutions	0.921	0.687	0.252
	Business dynamism	0.841	0.611	0.409
	Product market	0.805	0.529	0.414
	Labour market	0.781	0.488	0.428
	Financial system	0.812	0.616	0.490
	Innovation capability	0.801	0.716	0.702
	Macroeconomic stability	0.672	0.455	0.601

Note: *: 1- r^2 ratio is calculated according to formula (1)

Table 6 shows the pattern of country groups by considering similar indicators for a given VARCLUS component and calculating the average score of the components by a group. In factor-driven economies (Stage 1), natural capital and resource intensity are high but weaker in the other competitiveness indicators. Efficiency-driven economies (Stage 2) and the different transitions stages (1 to 2, and 2 to 3) are related more to the second indicator cluster where human capital, infrastructure and governance efficiency are relevant. Innovation-driven economies (Stage 3) are resilient mainly in the indicators belonging to the last (3) related cluster (institutions, business dynamism, innovation capability). In this analysis, we explored the pattern of country groups by including similar indicators in a given principal component and substituting appropriate values for such. These results are consistent with those observed in previous studies, such as Popescu et al. (2017), who applied hierarchical clustering to assess the global competitiveness of EU countries in terms of sustainable development.

Tab. 6 – VARCLUS component scores by country groups. Source: own research

Country groups	VARCLUS Components		
	1	2	3

Stage 1	0.413	-1.218	-0.902
Transition from 1 to 2	-0.513	-0.218	-0.410
Stage 2	-0.398	-0.019	-0.202
Transition from 2 to 3	-0.100	0.421	0.174
Stage 3	0.071	1.191	1.316
Explained Variance (%)	67.2	74.0	80.5

5. CONCLUSION

The main objective of this study was to explore the interrelations of economic competitiveness and sustainability and create an overall ranking of countries based on economic and sustainable competitiveness factors. We used a novel method of ranking, namely, the DRAPE analysis, which allows for different weights to be applied to diverse criteria and offers a posteriori variable detection by correlating the criteria with the PWR ranking. The classification of competitiveness elements into homogeneous clusters was performed by VARCLUS, which calculates similarities with the correlation coefficient and associates each group with a latent component. The benefit of the VARCLUS method is that it can characterise samples quickly by latent variables. The process of this method is even faster if it eliminates highly correlated variables from the models, which are more interpretable.

Contrary to the World Economic Forum approach, we employed the relative importance of indices (pillars) weights, which are needed to explore sustainable competitiveness positions. This research extends our knowledge of economic competitiveness related to sustainability, especially institutional environments and innovation capabilities. The 'Nordic model' seems to be promising in moving towards fair, sustainable and inclusive economic growth. Moreover, most EU states, led by Switzerland, Sweden, Finland, and Denmark, have the highest rankings regarding both competitiveness and sustainability. These findings are consistent with former research (Kiselakova et al., 2020; Valsecchi & Todeschini, 2021) that highlighted the leadership of Scandinavian countries and Switzerland, which are all competitive and sustainable.

Considering the analysis results, the previous national and economic competitiveness indicators are not suitable to support a comprehensive sustainable assessment. Many sustainability factors combine to make the global environment increasingly unpredictable and difficult for decision-makers. A new, complex indicator and ranking method should be considered for planning the convergence pathway of UN countries. Such an approach improves a development framework for assessing sustainable competitiveness

To conclude, improving sustainable competitiveness may be vulnerable to environmental issues and resource scarcity, but socio-economic dimensions must also be considered. It can provide a sustainable agenda for implementing the best-practice policy models in lower ranking and catching-up countries. The findings further support the insight provided by Siudek & Zawojska (2014), who demonstrated that firm-related factors (e.g., intangible assets, know-how, networks), government regulatory policies, and formal and informal institutions positively impact sustainable competitiveness.

The limitations of this research lie in the chosen pillars and variables as well as the cross-sectional nature of the research. Researching just one year may not be the most reliable way of studying the competitiveness of different countries, as it does not reflect changes (improvements or deterioration) in the competitiveness factors and positions.

Thus, further analysis of the interrelations of economic development and sustainability factors could shed additional light on how the two seemingly contrasting aspects of competitiveness can be optimally combined in an overall index. Preparing long-term solutions for global challenges, including recovery after the COVID-19 pandemic, requires accurate indicators to build on both socio-economic and environmental pillars of wellbeing and competitiveness. Such indicators are also essential for policymakers to continually monitor and analyse progress toward sustainable development goals (SDGs). Researchers may also consider applying more comprehensive measures to assess competitiveness on other levels of human activity such as regions, sectors, and organisations.

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APPENDIX:

Tab. 7 – Ranking of countries by both (GCI and GSCI) PWR (N=139). Source: SolAbility (2019); The World Bank (2019)

#	Country	PWR	#	Country	PWR	#	Country	PWR
1	Switzerland	11.281	51	Kazakhstan	1.224	101	Guatemala	0.539
2	Sweden	10.667	52	Georgia	1.210	102	Mongolia	0.523
3	Finland	10.335	53	Oman	1.194	103	Egypt	0.523
4	Denmark	9.320	54	Brunei	1.194	104	Iran	0.501
5	United Kingdom	6.455	55	Greece	1.193	105	Nicaragua	0.500
6	Germany	6.394	56	Colombia	1.184	106	Tanzania	0.482
7	Japan	5.703	57	Mexico	1.180	107	El Salvador	0.482
8	Netherlands	5.669	58	Montenegro	1.163	108	Cote d'Ivoire	0.480
9	Norway	5.516	59	Peru	1.138	109	Honduras	0.473
10	Luxembourg	5.220	60	Serbia	1.133	110	Senegal	0.472
11	Austria	5.021	61	Panama	1.124	111	Bangladesh	0.472
12	New Zealand	4.975	62	Armenia	1.110	112	Pakistan	0.472
13	Singapore	4.857	63	Azerbaijan	1.077	113	Laos	0.463
14	Canada	4.821	64	Philippines	1.057	114	Nigeria	0.456
15	Iceland	4.747	65	Bahrain	1.054	115	Guinea	0.440
16	Ireland	4.377	66	Belarus	1.046	116	Cameroon	0.433

17	France	4.341	67	Vietnam	1.026	117	Cape Verde	0.429
18	USA	3.958	68	Turkey	0.980	118	Ethiopia	0.412
19	Belgium	3.768	69	Kuwait	0.946	119	Benin	0.395
20	Australia	3.768	70	Brazil	0.943	120	Uganda	0.392
21	Korea	3.528	71	South Africa	0.912	121	Gabon	0.383
22	Estonia	3.306	72	Albania	0.888	122	Venezuela	0.373
23	Spain	3.127	73	Macedonia	0.858	123	Gambia	0.341
24	Israel	3.045	74	Jordan	0.853	124	Zambia	0.337
25	Czech Republic	2.862	75	Argentina	0.829	125	Burkina Faso	0.335
26	Slovenia	2.844	76	Moldova	0.828	126	Lesotho	0.315
27	Portugal	2.774	77	Morocco	0.827	127	Eswatini	0.310
28	United Arab Emirates	2.575	78	India	0.810	128	Zimbabwe	0.272
29	Italy	2.561	79	Ukraine	0.798	129	Mali	0.260
30	Malaysia	2.534	80	Seychelles	0.773	130	Malawi	0.249
31	Latvia	2.451	81	Dominican Republic	0.758	131	Angola	0.226
32	Poland	2.353	82	Bosnia and Herzegovina	0.735	132	Madagascar	0.223
33	Lithuania	2.236	83	Jamaica	0.721	133	Mozambique	0.215
34	Malta	2.070	84	Paraguay	0.711	134	Congo Rep.	0.184
35	China	2.049	85	Kenya	0.675	135	Burundi	0.134
36	Slovakia	1.979	86	Kyrgyzstan	0.669	136	Mauritania	0.130
37	Chile	1.976	87	Tunisia	0.668	137	Chad	0.109
38	Qatar	1.922	88	Ecuador	0.661	138	Haiti	0.087
39	Cyprus	1.708	89	Sri Lanka	0.650	139	Yemen	0.069
40	Romania	1.549	90	Trinidad and Tobago	0.636			
41	Bulgaria	1.466	91	Algeria	0.617			
42	Saudi Arabia	1.461	92	Rwanda	0.610			
43	Croatia	1.436	93	Lebanon	0.592			
44	Thailand	1.414	94	Namibia	0.591			
45	Hungary	1.369	95	Tajikistan	0.588			
46	Russia	1.286	96	Cambodia	0.579			
47	Costa Rica	1.285	97	Nepal	0.565			
48	Uruguay	1.280	98	Ghana	0.562			
49	Indonesia	1.260	99	Botswana	0.555			
50	Mauritius	1.247	100	Bolivia	0.541			