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Global Competitiveness of Europe: A Robust Assessment

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Abstract

National (global) competitiveness became the central issue during the global crisis. Using the values of the three main subdimensions of the Global Competitiveness Index, we propose alternative DEA-based competitiveness indicators. In our approach, the index is nested in the more general measure of the competitiveness-given-performance indicator. We find that globally competitive European countries do not transform competitiveness into income per capita efficiently. Decomposition of the scores suggests that most of the relative inefficiency concentrates in innovation activity. The results proved robust against the CCR model used in previous research as well as principal component analysis.

Keywords

Global Competitiveness Index, Economic Performance, Data Envelopment Analysis, European Union

I. Introduction

In the course of globalization, economic competition between countries has intensified in the past decades both within the European Union and worldwide. National (global) competitiveness became the central issue during the global crisis not only for small open economies. Exposure to external shocks made every country of the global network vulnerable and forced to compete for resources, environment, or markets. The notion of competitiveness itself has evolved from a microeconomic feature of the exporting firm[4] to the broader concept of global competitiveness which characterizes the national economy.

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[4] Ability of a firm or a nation to offer products and services that meet the quality standards of the local and world markets at prices that are competitive and provide adequate returns on the resources employed or consumed in their producing (Business Dictionary).

Global competitiveness has, however, been far from being defined and construed in a universally accepted way. Krugman (1994) identified competitiveness with productivity and expressed skepticism about the term itself. Berger (2008) lists the "ability of a nation to sell its goods to another nation", "ability of a nation to earn", "ability to adjust to changes in the external environment" and the "national ability to attract scarce mobile resources". Recent assessments of competitiveness build on the ideas articulated in Porter (1990) and later combining inputs (often from government investments) and incentives (competition, openness) as drivers of higher productivity along with the quality of local demand conditions and the presence of the related and supporting industries into an integrated framework.

Empirical work is represented by Delgado et al. (2012) employing parametric regression analysis for determining the impact of significant factors attributed to competitiveness affecting productivity. A competitiveness index is then constructed from the regressors as a weighted sum with *fixed* weights based on estimates. The causal link between economic growth and competitiveness in 114 countries has been established by Kordalska and Olczyk (2016) using Granger causality tests.

Various approaches would require the use of different indicators to assess competitiveness. In the following analysis, we adopt the definition of national competitiveness from WEF (2018) as "the set of institutions, policies and factors that determine the level of productivity". This definition underlies the widely used indicator of competitiveness – the GCI.

The Global Competitiveness Index (GCI) aspires to offer impartial information that allows policymakers from the public and private sectors to better understand the main drivers of growth. Theoretically, the GCI assumes productivity to be the main determinant of long-term growth. Therefore, identified by empirical and theoretical research, the factors and institutions determining improvements in productivity are evaluated in 114 indicators which are further grouped into twelve pillars comprising institutions, infrastructure, macroeconomic environment, health and primary education, higher education and training, goods market efficiency, labour market efficiency, financial market development, technological readiness, market size, business sophistication, and innovation.[5] These pillars are in turn organized into three subindexes: basic requirements, efficiency enhancers, and innovation and sophistication factors. In the final calculation of the overall GCI, the three subindexes are assigned different weights. These depend on each economy's stage of development, proxied by its GDP per capita and the share of raw materials exports. To expand the idea of discrimination between the countries by means of different weights, we propose that the weights are assigned strictly individually. Each country would choose its weights so as to accentuate its better performance in each particular domain and maximize its relative-to-others score. In this sense, we break the link between weights and economic performance which underlies the construction of the GCI, but on the other hand, we allow for further extension of the model to take in economic performance indicators. Thus, we reject the idea of *ex ante* assigned weights

[5] For more on some of these topics, see e.g. Laboutková and Vymětal (2017), Ravšelj and Aristovnik (2017), or Uhrová and Skalka (2016).

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letting a country's economic policy preferences be reflected in the proposed indicator. Countries with the highest competitiveness index (potential) may not be able to transform it into economic performance to the full extent. Efficiency of the transformation could be measured in the same way as efficiency of production processes. A well-established non-parametric technique of data envelopment analysis (DEA) can be employed in this case. Šegota et al. (2017) used a basic CCR model in this framework which can suffer from untreated slacks. We improve on that approach by employing an SBM model to tackle possible slacks saving through CCR for a robustness test.

We proceed by delineating two basic data envelopment analysis models for measuring efficiency in Section II. We argue that DEA models can provide deeper insight into factors contributing to the object evaluation than the commonly used synthetic index could. In Section III we outline a subsystem analysis in the framework of DEA. These analytical tools are employed to assess the competitiveness of 30 European countries within the global environment. The results are presented in Section IV and confronted with an additional statistical tool – principal component analysis. Section V concludes.

II. Nonparametric approach: DEA models

Besides the standard synthetic indices (or more complex productivity measures) with *ex ante* assigned weights of constituent subdimensions, we propose that weights are determined individually for each country. To assess technical efficiency, the general conceptual formula is used:

$$efficiency = \frac{outputs}{inputs} \tag{1}$$

Index measures can be arrived at by collapsing inputs in the expression (1) to a fixed value (most often the unit). In classical DEA, as originally proposed by Charnes et al. (1978), every subject under evaluation – called the decision-making unit, DMU – aggregates its inputs and outputs by means of individually set weights so that the ratio (1) is maximized. Alternatively, one can minimize the reverse fraction. In order to avoid unboundedness, a constraint is imposed so that the resulting efficiency score cannot exceed unit which should also hold if any of the remaining $n - 1$ DMUs uses the weights μ and ν of DMU_0 under consideration. For n subjects transforming m inputs into s outputs the problem is formulated as:

$$\min \quad z_0(\mu, \nu) = \frac{\sum_{i=1}^{m} x_{i0}\nu_i}{\sum_{r=1}^{s} y_{rj}\mu_r} \qquad (i = 1, 2, \ldots, m) \tag{2}$$

$$\text{s.t.} \quad \frac{\sum_{i=1}^{m} x_{ij}\nu_i}{\sum_{r=1}^{k} y_{rj}\mu_r} \geq 1 \qquad (j = 1, 2, \ldots, n) \tag{3}$$

$$\mu_r \geq 0, \; \nu_i \geq 0 \qquad (r = 1, 2, \ldots, s) \tag{4}$$

Linearized, the basic CCR output-oriented (CCR-O) model can be written as:

$$\min \quad v^T x_0 \tag{5}$$

$$\text{s.t.} \quad -v^T X + u^T Y \geq 0^T \tag{6}$$

$$u^T y_0 = 1 \tag{7}$$

$$u \geq 0, \ v \geq 0 \tag{8}$$

Interpreted from the dual perspective of linear programming, the efficiency value can be viewed as an indirect distance measure from the efficiency frontier which envelops input and output data organized in matrices X and Y and is constructed from the *best practice* DMUs which are determined in the course of optimization and whose efficiency score (value of the objective function (5)) is equal to unit. An input-oriented CCR-I model can be shown to yield the same efficiency scores as CCR-O (e.g. Cooper et al., 2007).
Alternative measure of the distance was proposed by Tone (2001). Defining slack variables as deviations of DMU's inputs x_0 and outputs y_0 from the efficiency boundary as:

$$\begin{aligned} s^- &= x_0 + X\lambda \\ s^+ &= Y\lambda - y_0, \end{aligned} \tag{9}$$

a non-oriented slack-based measure (SBM) is determined by the optimization:

$$\min_{\lambda,\, s^+,\, s^-} \quad \rho = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{i0}}{1 + \frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{r0}} \tag{10}$$

$$\begin{aligned} \text{s.t.} \quad & x_0 = X\lambda + s^- \qquad (11) \\ & y_0 = Y\lambda - s^+ \\ & \lambda \geq 0, \\ & s^- \geq 0, \ s^+ \geq 0. \end{aligned}$$

One may give the model input or output orientation by omitting output or input slacks respectively from (10) obtaining thus SBM-I or SBM-O efficiency measures. Both CCR and SBM measures can be used to decompose the overall efficiency to contributing factors. DEA models provide efficiency values relative to other units in the selected sample. At this expense one obtains individual weights and benchmarks as a theoretical basis for possible policy action.

III. Subsystem analysis of the EU countries

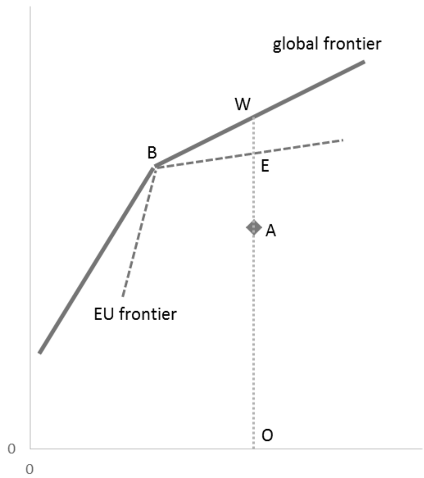
To analyse EU countries from the global perspective, we borrow the idea of Thanassoulis and Portela (2001). We construct two efficiency frontiers – (i) global world frontier by a *sbmef* model acting as a reference boundary and (ii) EU frontier modelled by *sbmef_eu* that only comprises EU countries and providing *within-group* efficiency. This enables us to decompose overall efficiency to the component attributable to DMU (country) and the second attributable to the group.

Within-group DEA efficiency is calculated by considering DMUs belonging to the EU subsystem. The overall DEA efficiency is determined which cannot exceed the *within-group* score attributable to the individual country. Efficient units of individual groups may prove inefficient relative to some global units. Dividing overall score by the group's one yields component attributable to group, thus:

sbmef (overall) score =
sbmef_eu score (attributable to country) × ***EU/world*** (attributable to EU)

In this way, the best practice of the subsystem is compared to that of the superior system. Graphical representation of the merit of the decomposition for an output-oriented model is depicted in Figure 1.

Figure 1: Efficiency of the subsystem



Source: Authors' elaboration

Schematically, inputs are represented on the horizontal while outputs are on the vertical axis. Output-oriented efficiency with respect to the global frontier ef_{glob} (A) = OA/OW, efficiency within the EU subsystem ef_{EU} (A) = OA/OE. For country *A*, the ratio OE/OW presents the efficiency of the EU wrt the world . The value cannot exceed 1, and is equal exactly to 1 solely if a country constitutes both EU and the world boundary line as in the case of country *B*, whose efficiency ef_{glob} (B) = ef_{EU} (B) = 1. Concerning the decomposition of DEA-based indexes, the same reasoning as for efficiencies applies.

IV. Results and robustness check

Empirical application of the techniques described above involve the calculation of optimizations (5)-(8) or (10)-(11). Data entering the models were adopted from WEF (2018) for three subindexes of GCI and World Bank (2018) for GDP per capita in PPP. Our dataset comes from those countries whose income p.c. exceeds 2000 USD.

We believe it constitutes a sufficient global background for assessing EU countries. On the upper end, we excluded Luxembourg and Qatar from the dataset due to excessively outlying income p.c. values to prevent unrealistic benchmarking, leaving the dataset with n = 87 countries (DMUs). Descriptive statistics of the data are provided in Table A2 in Annex. Concentrating further on the performance of the European countries, "EU" will be henceforth referred to as a group comprising EU-28 before Brexit less Luxembourg, and with Switzerland and Norway added (i.e. 29 countries in the EU subset). The models' orientation was determined so as to extract information on competitiveness.

Table 1: Overview of DEA models employed

model	type	variables	
		outputs	inputs
ccri	CCR-O	3 sub-indices of GCI	1
sbmi	SBM-O	3 sub-indices of GCI	1
sbmi_eu	SBM-O	3 sub-indices of GCI	1
ccref	CCR-I	GDP p.c. (PPP)	3 sub-indices of GCI
sbmef	SBM-I	GDP p.c. (PPP)	3 sub-indices of GCI
sbmef_eu	SBM-I	GDP p.c. (PPP)	3 sub-indices of GCI

Source: Authors' elaboration

Table 1 provides an overview of the models and variables used. Global models involve 87 optimizations to be calculated, while those for the EU are just 29. Evaluating the competitiveness of EU countries, we computed global and group models to determine global and EU frontiers (as described in Section IV) employing sbmi and sbmi_eu models. In Annex table A1 sbmi scores for all countries are provided. There are three worldwide efficient countries – Singapore, Switzerland, and US – with sbmi scores equal to 1. This corresponds to the three countries scoring the best in the GCI. Here we can point out the relativeness of the DEA approach letting all three DMUs be potentially benchmarked against. Focusing on GCI, one would opt for the highest GCI (Switzerland) solely.

A detailed view on the solutions for lambda in (10)-(11), however, reveal that Singapore and the US only present benchmarks for themselves, indicating outlying DMUs in the DEA sense. Other countries with a competitiveness indicator less than unit are clustered around Switzerland, which acts as a general benchmark. EU group members have thus no particular frontier and there is no difference between benchmarking against the world and the EU boundary line. Therefore, *sbmi* and *sbmi_eu* scores are identical and EU/world is unit as Table 2 for selected countries states. This particular dataset was not therefore allowed to demonstrate the capabilities of DEA to the full.

In the case of performance-given-competitiveness evaluation, the only globally efficient DMU is Singapore, for EU the best practice is Ireland (which would correspond to the point E in Figure 1). Global EU countries' scores now deviate from their global score. From the ratio of EU vs world performance, one can state that over 70% of the efficiency is attributable to the EU, as described in Section III. sbmef_eu scores present efficiency attributable to individual countries within the system as benchmarked against Ireland.

Comparing index and efficiency scores makes it clear that the best scoring and therefore most "endowed" EU countries – Switzerland (sbmi = 1), UK (0.924), Germany (0.959) or Finland (0.936) or Netherlands (0.967) did not manage to transform their potential into high income p.c. – compared to Singapore with an efficiency equal to 1. The EU thus seems to address the issue and analyse sources of relative underperformance.

Table 2: Selected results for EU countries

	index			efficiency		
	sbmi	*sbmi_eu*	*EU/world*	*sbmef*	*sbmef_eu*	*EU/world*
Austria	0.896	0.896	1	0.482	0.670	0.719
Belgium	0.884	0.884	1	0.442	0.616	0.719
Czechia	0.802	0.802	1	0.308	0.430	0.717
Finland	0.936	0.936	1	0.452	0.629	0.719
France	0.878	0.878	1	0.413	0.575	0.719
Germany	0.959	0.959	1	0.529	0.736	0.719
Hungary	0.696	0.696	1	0.229	0.319	0.717
Ireland	0.876	0.876	1	0.712	1	0.712
Italy	0.771	0.771	1	0.317	0.441	0.719
Netherlands	0.967	0.967	1	0.571	0.795	0.719
Poland	0.739	0.739	1	0.240	0.335	0.717
Romania	0.666	0.666	1	0.185	0.258	0.717
Slovakia	0.723	0.723	1	0.263	0.366	0.717
Spain	0.787	0.787	1	0.326	0.455	0.717
Switzerland	1	1	1	0.686	0.954	0.719
United Kingdom	0.924	0.924	1	0.442	0.615	0.718

Source: Authors' calculation

Decomposition of SBM score can help identify sources of inefficiency. The objective function (10) penalizes DMU for (the sum of relative) slacks. For SBM-I model, $\frac{1}{m}\sum_{i=1}^{m} s_i^-/x_{i0}$ presents the total penalty, s_i^-/x_{i0} can be thus viewed as the i^{th} input contribution to overall inefficiency. We can therefore determine how particular domains assessed by GCI subindexes contributed to the overall score in relative terms. Higher values would be associated with relatively weak performance in the area. The results of decomposition for selected countries are exhibited in Table 3.

Clearly, in an efficient country (Singapore), no inefficiencies are present. For the other DMUs, one can observe different patterns of inefficiency distribution across the three areas evaluated by GCI subindexes. Inefficiencies add up to 1 (100%). BASICR stands for basic requirements, EFF for efficiency enhancers, and INNOV for innovation and sophistication factors. From a global perspective, the most inefficiency concentrates in innovation activity. Policy measures should be advisably based on the analysis of best performing benchmark DMU. For EU countries the same recommendations hold since the results do not deviate much from the global pattern, as the last row of Table 3 makes clear.

There are, however, some significant individual deviations from the average pattern. For instance, the UK exhibits most inefficiency in BASICR while being very strong in EFF. Strong performance in EFF is apparent in Canada as well, with the most inefficient area being INNOV. In terms of innovation activity, Israel and Japan show the most efficiency. Interestingly, V4 members (Czechia, Slovakia, Poland, and Hungary) share a common pattern of inefficiency distribution with a slightly greater relative potential improvement in innovation.

Table 3: Decomposition of inefficiency (selected countries)

DMU	Score	Inefficiency			
		BASICR	EFF	INOV	Total
Belgium	0.884	0.421	0.246	0.333	1
Bulgaria	0.703	0.268	0.225	0.507	1
Canada	0.894	0.329	0.066	0.605	1
Colombia	0.688	0.349	0.213	0.438	1
Czechia	0.802	0.263	0.220	0.517	1
Estonia	0.817	0.192	0.221	0.588	1
Finland	0.936	0.336	0.324	0.340	1
Germany	0.959	0.544	0.168	0.288	1
Hungary	0.696	0.285	0.208	0.507	1
China	0.808	0.282	0.222	0.496	1
Israel	0.901	0.504	0.314	0.181	1
Japan	0.928	0.553	0.207	0.240	1
New Zealand	0.905	0.178	0.129	0.693	1
Poland	0.739	0.265	0.203	0.532	1
Russia	0.734	0.275	0.212	0.513	1
Singapore	1	0	0	0	
Slovakia	0.723	0.281	0.232	0.486	1
Spain	0.787	0.296	0.206	0.498	1
Ukraine	0.658	0.339	0.244	0.417	1
United Kingdom	0.924	0.532	0.073	0.395	1
World average	**0.769**	**0.289**	**0.255**	**0.456**	**1**
EU average	***0.819***	***0.299***	***0.258***	***0.443***	***1***

Source: Authors' calculation

For a robustness check we computed index and efficiency scores employing a CCR model (5)-(8). Since we are not interested in values of scores *per se*, believing them to be only a starting point for deeper analysis and formulating policy measures, we test whether various evaluation techniques generate similar ranking[6]. For this purpose, we produce

[6] Due to the construction of the objective function, SBM and CCR scores may significantly differ in values while correlate positively. One can show that SBM capturing slacks never exceeds CCR score (Tone, 2001).

a correlation matrix of variables containing ranking scores – *rgci* for GCI ranking, *rsbmi* for SBM-computed index, *rccri* for CCR-computed index, *rsmbef* for SBM efficiency (the baseline dealt with above), *rccref* for CCR efficiency. From Table 4 it is obvious that CCR and SBM efficiency rankings are highly correlated (0.83), the more so are index scores (0.97). High index or efficiency scores are naturally associated with lower ranking numbers, hence negative correlations between scores and ranks.

Table 4: Correlations and rank correlations matrix

	sbmi	*rsbmi*	*ccri*	*rccri*	*sbmef*	*rsbmef*	*ccref*	*rccref*	*Gci*	*rgci*	*pc1*	*rpc1*
sbmi	1											
rsbmi	−0.97	1										
ccri	0.98	−0.95	1									
rccri	−0.94	0.96	−0.97	1								
sbmef	0.83	−0.79	0.86	−0.83	1							
rsbmef	−0.82	0.81	−0.86	0.87	−0.95	1						
ccref	0.85	−0.80	0.87	−0.84	1.00	−0.95	1					
rccref	−0.83	0.82	−0.87	0.87	−0.95	1.00	−0.95	1				
gci	0.99	−0.94	0.98	−0.94	0.83	−0.80	0.84	−0.81	1			
rgci	−0.95	0.96	−0.95	0.96	−0.79	0.80	−0.80	0.80	−0.96	1		
pc1	−1.00	0.97	−0.98	0.95	−0.83	0.83	−0.85	0.83	−0.99	0.95	1	
rpc1	−0.96	1.00	−0.96	0.97	−0.79	0.82	−0.81	0.83	−0.94	0.97	0.97	1

All correlations significant at 1% level.
Source: Authors' calculation

Since variables correlated (as Table A2 in Annex demonstrates), principal component analysis (PCA) can complement the robustness study. We thus assume that the three subindices gauge the solid phenomenon of competitiveness from the three perspectives as opposed to the "synthetic" nature of aggregated index. We employed a statistical technique to reduce the dimensionality of output data (organized in matrix Y) aiming to replace it by a set of $\mathrm{PC}_r,\ r = 1,\ 2,\ \ldots s$ (s is number of original variables). Principal components are computed by optimization:

$$PC_r = \sum_{k=1}^{s} l_{kr} Y_k, \quad \text{s.t. } \operatorname{var}(PC_r) \to \max, \quad \sum_{k=1}^{s} l_{kr}^2 = 1 \tag{12}$$

As a result, one can choose a certain number of principal components acting as new data while retaining an arbitrary share of original information. For three original data of GCI subindexes, the PCA results are summarized in Table 5.

Table 5: Eigenanalysis of covariance matrix

Component	Eigenvalue	Proportion	Cumulative
1	1.139	0.929	0.929
2	0.056	0.045	0.975
3	0.031	0.025	1.000

Source: Authors' calculation

The last column of the table displays a cumulative percentage of the original information contained in consecutively added principal components. The first component PC1 contains a fair 93% of original information. In the results Table A2 in Annex, *pc1* variable values are provided along with the associated ranking *rpc1*. We next check correlation between the PC1 ranking and rankings from DEA models finding a high level of correlation – 0.97 with CCR and a perfect correlation with SBM.

V. Conclusion

We carried out an analysis of European countries regarding their competitiveness as well as efficiency of transformation of competitiveness into economic performance. A robustness check made the statements a reliable basis for policy-making.

The proposed technique of assessing competitiveness against the economic performance of the country brings with it the possibility of not merely producing an index value or rank but a deeper insight into sources of inefficiency and indicate common patterns for some country groups. A competitiveness index is in our approach nested in the more general measure of the competitiveness-versus-performance indicator. EU countries do not exhibit any significant deviation from the world distribution of relative inefficiency across the dimensions featuring relative strength in basic rights and weakness in innovation activity. However, V4 members share a common pattern of inefficiency distribution, revealing a slightly greater shortfall at a relative loss in innovation.

Though index values obtained from the DEA model generate nearly identical ranking of countries as the commonly used index, additional information could be extracted from optimization results. Generally, benchmarking against more than a single subject – as against Switzerland in the specific case of this study – would involve linear combinations of multiple efficient subjects, revealing the relative strengths and weaknesses of the analyzed subjects that are not obvious from merely comparing the constituent subindexes. Refining the design further, weight restrictions reflecting policymaker preferences can be directly embodied in the optimization process. Finally, expanding the assessment to more than one dimension of economic performance, not merely GDP p.c., more advantages of DEA-based models could be revealed.

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Appendix

Table A1: Scores, ranks, principal component and data

	EU	*sbmi*	*rsbmi*	*ccri*	*rccri*	*sbmef*	*rsbmef*	*ccref*	*rccref*	GCI	*rgci*	*pc1*	*rpc1*	BASICR	EFF	INOV
Albania	0	0.673	72	0.715	77	0.094	73	0.098	73	4.18	74	1.526	72	4.57	4.01	3.55
Algeria	0	0.617	85	0.689	84	0.109	67	0.112	68	4.07	85	2.359	85	4.40	3.68	3.13
Armenia	0	0.679	67	0.710	79	0.072	75	0.075	75	4.19	72	1.452	70	4.51	4.05	3.65
Austria	1	0.896	17	0.904	20	0.482	15	0.537	12	5.19	20	−1.995	18	5.70	5.03	5.30
Australia	0	0.872	22	0.917	19	0.474	17	0.487	20	5.25	18	−1.662	22	5.70	5.29	4.68
Azerbaijan	0	0.758	39	0.778	47	0.144	60	0.153	58	4.69	34	0.207	40	4.93	4.44	4.22
Bahrain	0	0.764	36	0.806	34	0.403	25	0.412	25	4.54	42	0.067	37	5.08	4.62	4.05
Belgium	1	0.884	19	0.894	23	0.442	21	0.489	19	5.23	19	−1.799	19	5.48	5.15	5.18
Bhutan	0	0.655	83	0.721	73	0.065	78	0.068	77	4.10	81	1.807	84	4.61	3.68	3.53
Botswana	0	0.665	77	0.740	67	0.134	62	0.137	62	4.30	62	1.611	76	4.73	3.87	3.44
Brazil	0	0.668	75	0.717	75	0.117	64	0.124	64	4.14	77	1.624	77	4.08	4.27	3.66
Brunei	0	0.690	60	0.790	42	0.607	8	0.616	9	4.52	44	1.139	58	5.05	4.06	3.46
Bulgaria	1	0.703	55	0.764	52	0.170	55	0.177	54	4.46	48	0.979	54	4.77	4.40	3.57
Canada	0	0.894	18	0.947	11	0.467	18	0.491	18	5.35	14	−2.016	17	5.72	5.52	4.82
Colombia	0	0.688	61	0.742	63	0.111	66	0.117	65	4.29	65	1.295	64	4.33	4.38	3.67
Costa Rica	0	0.743	42	0.770	50	0.136	61	0.144	61	4.50	46	0.441	43	4.82	4.43	4.08
Croatia	1	0.687	63	0.746	61	0.188	51	0.192	52	4.19	73	1.259	62	4.77	4.11	3.55
Cyprus	1	0.724	47	0.771	49	0.295	34	0.302	34	4.30	63	0.681	47	4.92	4.36	3.79
Czechia	1	0.802	28	0.848	28	0.308	33	0.315	33	4.77	30	−0.562	28	5.35	4.86	4.24
Denmark	1	0.918	12	0.927	16	0.496	13	0.535	13	5.39	12	−2.361	12	5.90	5.26	5.28
Estonia	1	0.817	26	0.886	25	0.282	36	0.285	37	4.85	28	−0.854	26	5.66	4.92	4.20
Finland	1	0.936	7	0.937	15	0.452	20	0.496	17	5.49	9	−2.651	8	5.98	5.30	5.48
France	1	0.878	20	0.890	24	0.413	24	0.449	24	5.18	21	−1.706	20	5.54	5.1	5.07

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	EU	*sbmi*	*rsbmi*	*ccri*	*rccri*	*sbmef*	*rsbmef*	*ccref*	*rccref*	GCI	*rgci*	*pc1*	*rpc1*	BASICR	EFF	INOV
Georgia	0	0.662	78	0.754	57	0.081	74	0.082	74	4.28	66	1.553	74	4.82	4.06	3.23
Germany	1	0.959	5	0.966	6	0.529	11	0.586	11	5.65	5	-3.005	5	5.97	5.53	5.65
Greece	1	0.679	68	0.717	76	0.210	47	0.219	46	4.02	86	1.435	69	4.58	4.05	3.60
Guatemala	0	0.668	74	0.694	83	0.061	81	0.065	81	4.08	83	1.654	79	4.26	4.02	3.70
Hong Kong	0	0.933	8	0.983	4	0.630	7	0.640	7	5.53	6	−2.676	7	6.26	5.58	4.96
Hungary	1	0.696	57	0.764	53	0.229	43	0.242	43	4.33	58	1.095	56	4.65	4.44	3.52
Chile	0	0.763	38	0.834	31	0.205	48	0.216	48	4.71	32	0.007	33	5.13	4.83	3.86
China	0	0.808	27	0.849	27	0.145	59	0.149	60	5.00	26	−0.636	27	5.32	4.88	4.33
Iceland	1	0.857	25	0.920	18	0.481	16	0.501	16	4.99	27	−1.435	24	5.88	4.77	4.77
India	0	0.751	41	0.770	51	0.058	82	0.064	82	4.59	38	0.337	41	4.68	4.47	4.29
Indonesia	0	0.769	34	0.790	43	0.103	69	0.110	69	4.68	35	0.026	35	4.98	4.52	4.29
Iran	0	0.680	65	0.754	57	0.154	57	0.157	57	4.27	68	1.360	65	4.82	3.99	3.51
Ireland	1	0.876	21	0.894	22	0.712	3	0.754	3	5.16	23	−1.693	21	5.68	5.09	4.93
Israel	0	0.901	15	0.944	12	0.355	30	0.411	26	5.31	16	−2.092	16	5.48	5.12	5.53
Italy	1	0.771	33	0.780	46	0.317	32	0.348	31	4.54	43	0.022	34	4.88	4.46	4.45
Jamaica	0	0.694	58	0.718	74	0.070	76	0.075	76	4.25	69	1.233	60	4.52	4.12	3.81
Japan	0	0.928	9	0.948	10	0.432	23	0.487	21	5.49	10	−2.513	9	5.66	5.39	5.55
Jordan	0	0.707	54	0.725	71	0.097	71	0.105	71	4.30	64	1.034	55	4.56	4.15	3.96
Kazakhstan	0	0.677	70	0.746	62	0.200	50	0.211	49	4.35	55	1.375	66	4.59	4.32	3.39
Korea	0	0.867	23	0.903	21	0.368	27	0.387	28	5.07	25	−1.555	23	5.77	4.93	4.85
Kuwait	0	0.684	64	0.764	54	0.508	12	0.513	15	4.43	51	1.271	63	4.88	4.07	3.47
Latvia	1	0.720	49	0.784	44	0.220	45	0.225	45	4.40	53	0.693	48	5.01	4.40	3.65
Lithuania	1	0.764	35	0.807	33	0.268	37	0.274	38	4.58	40	0.059	36	5.15	4.57	4.04
Malaysia	0	0.860	24	0.871	26	0.268	38	0.289	36	5.17	22	−1.424	25	5.55	4.94	4.91
Malta	1	0.789	29	0.847	29	0.359	28	0.366	29	4.65	36	−0.353	29	5.41	4.61	4.20

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	EU	*sbmi*	*rsbmi*	*ccri*	*rccri*	*sbmef*	*rsbmef*	*ccref*	*rccref*	GCI	*rgci*	*pc1*	*rpc1*	BASICR	EFF	INOV
Mauritius	0	0.734	45	0.784	44	0.174	53	0.180	53	4.52	45	0.546	46	5.01	4.28	3.93
Mexico	0	0.715	50	0.760	56	0.157	56	0.163	56	4.44	49	0.864	51	4.59	4.43	3.84
Moldova	0	0.603	87	0.662	87	0.040	84	0.041	84	3.99	88	2.574	87	4.22	3.75	3.00
Montenegro	0	0.659	81	0.709	80	0.132	63	0.137	63	4.15	75	1.733	80	4.42	4.08	3.40
Morocco	0	0.680	66	0.750	60	0.065	77	0.067	79	4.24	70	1.385	67	4.79	3.94	3.56
Nepal	0	0.605	86	0.682	86	0.019	86	0.020	86	4.02	87	2.557	86	4.36	3.56	3.07
Netherlands	1	0.967	4	0.977	5	0.571	9	0.619	8	5.66	4	−3.154	3	6.24	5.46	5.62
New Zealand	0	0.905	14	0.952	7	0.384	26	0.388	27	5.37	13	−2.217	13	6.05	5.43	4.81
Norway	1	0.921	11	0.942	13	0.718	2	0.755	2	5.40	11	−2.412	11	6.02	5.29	5.19
Oman	0	0.711	52	0.801	39	0.357	29	0.361	30	4.31	61	0.822	50	5.12	4.19	3.61
Panama	0	0.737	44	0.801	39	0.205	49	0.210	50	4.44	50	0.476	44	5.12	4.29	3.89
Peru	0	0.662	79	0.727	70	0.100	70	0.105	70	4.22	71	1.644	78	4.45	4.22	3.33
Philippines	0	0.700	56	0.741	65	0.064	80	0.067	80	4.35	56	1.109	57	4.6	4.27	3.72
Poland	1	0.739	43	0.806	35	0.240	41	0.251	41	4.59	39	0.394	42	4.99	4.65	3.75
Portugal	1	0.772	32	0.805	37	0.254	40	0.264	40	4.57	41	−0.051	32	5.12	4.58	4.18
Romania	1	0.666	76	0.740	66	0.185	52	0.195	51	4.28	67	1.530	73	4.57	4.28	3.28
Russia	0	0.734	46	0.795	41	0.225	44	0.234	44	4.64	37	0.501	45	4.92	4.59	3.76
Rwanda	0	0.693	59	0.723	72	0.016	87	0.017	87	4.35	57	1.243	61	4.62	3.95	3.87
Saudi Arabia	0	0.782	31	0.828	32	0.465	19	0.471	23	4.83	29	−0.237	31	5.28	4.69	4.12
Serbia	0	0.653	84	0.710	78	0.111	65	0.114	67	4.14	78	1.790	82	4.54	3.99	3.31
Singapore	0	1	1	1	1	1	1	1.000	1	5.71	3	−3.138	4	6.34	5.72	5.25
Slovakia	1	0.723	48	0.775	48	0.263	39	0.272	39	4.33	59	0.698	49	4.83	4.46	3.76
Slovenia	1	0.763	37	0.804	38	0.285	35	0.299	35	4.48	47	0.102	38	5.14	4.39	4.18
South Africa	0	0.715	51	0.741	64	0.106	68	0.117	66	4.32	60	0.900	52	4.28	4.39	4.14
Spain	1	0.787	30	0.836	30	0.326	31	0.338	32	4.70	33	−0.303	30	5.15	4.84	4.17

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	EU	*sbmi*	*rsbmi*	*ccri*	*rccri*	*sbmef*	*rsbmef*	*ccref*	*rccref*	GCI	*rgci*	*pc1*	*rpc1*	BASICR	EFF	INOV
Sri Lanka	0	0.673	73	0.706	81	0.096	72	0.104	72	4.08	84	1.567	75	4.51	3.81	3.76
Sweden	1	0.942	6	0.951	8	0.529	10	0.588	10	5.52	7	−2.751	6	6.00	5.30	5.57
Switzerland	1	1	1	1	1	0.686	4	0.750	4	5.86	1	−3.677	1	6.39	5.65	5.86
Taiwan	0	0.905	13	0.922	17	0.492	14	0.521	14	5.33	15	−2.153	14	5.84	5.25	5.12
Tajikistan	0	0.661	80	0.689	84	0.024	85	0.026	85	4.14	79	1.765	81	4.40	3.74	3.72
Thailand	0	0.754	40	0.805	36	0.147	58	0.151	59	4.72	31	0.204	39	5.06	4.62	3.92
Trinidad and Tobago	0	0.674	71	0.728	69	0.237	42	0.248	42	4.09	82	1.497	71	4.40	4.24	3.52
Turkey	0	0.708	53	0.763	55	0.211	46	0.219	47	4.42	52	0.924	53	4.75	4.40	3.65
Ukraine	0	0.658	82	0.699	82	0.065	79	0.068	78	4.11	80	1.799	83	4.18	4.09	3.55
United Arab Emirates	0	0.901	16	0.942	13	0.662	5	0.676	6	5.30	17	−2.120	15	6.02	5.23	4.93
United Kingdom	1	0.924	10	0.949	9	0.442	22	0.479	22	5.51	8	−2.457	10	5.65	5.55	5.34
United States	0	1	1	1	1	0.639	6	0.717	5	5.85	2	−3.195	2	5.54	6.01	5.80
Uruguay	0	0.688	62	0.753	59	0.172	54	0.176	55	4.15	76	1.216	59	4.81	4.20	3.47
Viet Nam	0	0.678	69	0.733	68	0.053	83	0.055	83	4.36	54	1.418	68	4.52	4.24	3.49

Source: Authors' calculation

Table A2: Descriptive statistics of the data

Statistics on Input/Output Data	BASICR	EFF	INOV	YPCPPP
Max	5.92	6.44	7.00	93905.5
Min	3.61	3.99	4.14	2079.9
Average	4.92	5.42	5.83	31391.5
SD	0.58	0.56	0.75	19743.2

Correlation	BASICR	EFF	INOV	YPCPPP
BASICR	1	0.89	0.87	−0.80
EFF	0.89	1	0.91	−0.73
INOV	0.87	0.91	1	−0.66
YPCPPP	−0.80	−0.73	−0.66	1

Source: Authors' elaboration