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Bibliometric approach of factors affecting scientific productivity in environmental sciences and ecology

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HIGHLIGHTS

► We model the correlation between academic output in environmental sciences and its influence factors.
► We discuss the position of 92 countries by scientific productivity and Environmental Performance Index.
► We propose a ranking of countries considering the concern about the environment.

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ABSTRACT

Different academic bibliometric studies have measured the influence of economic, political and linguistic factors in the academic output of countries. Separate analysis in different fields can reveal specific incentive factors. Our study proves that the Environmental Performance Index, computed by Yale University, is highly significant ($p<0.01$) for the productivity of research and development activities in environmental sciences and ecology. The control variables like education financing, publishing of ISI Thomson domestic journals and the English language are also significant. The methodology uses Ordinary Least Squares multiple regressions with convincing results ($R^2=0.752$). The relative positions of the 92 countries in the sample are also discussed. We draw up a ranking of the countries' concern for the environment, considering evenly the scientific productivity and the environment quality. We notice huge differences concerning the number of inhabitants and population income between the countries that dominate the classification and those occupying the last positions.

1. Introduction

In the last decades, more and more countries have aimed for scientific and technological development. This endeavour enables the development of a competitive economy with a structure which favours the highly qualified labour force sectors. The extreme importance of research and development activities (R&D) requires a rigorous pursuit of results, factors and efficiency from all angles. Scientometrics has thus appeared, often using in practice the bibliometric analysis as a measurement of the impact of scientific publications. The mechanisms that generate scientific productivity at a country level (Gantman, 2012), field (Campanario et al., 2006; Hu et al., 2010) or particular topic (Almind and Ingwersen, 1997) can be described through general and specific statistical methods.

The benefits of implementing the scientific output were analysed from the viewpoint of productivity, with positive consequences on the economic activities (Cole and Phelan, 1993) and using an approach based on comparative differences across countries (Leydesdorff and Gauthier, 1996). Some studies lay more emphasis on the factors that influence scientific output. Gantman (2012) conducted an investigation of 147 countries showing that the research financing opportunities influence all research fields. Instead, linguistic, political and motivational factors have only a selective influence, with major differences between social-humanities sciences and natural sciences. For some research areas we can easily identify motivational incentives (Agricultural Sciences, for example) while for other areas this mechanism is more difficult to identify (Mathematics).

As a consequence, a different bibliometric approach for scientific sectors can be useful. Some articles evaluate research issues in specific topics in environmental sciences and ecology: solid waste (Fu et al., 2010), atmospheric environment (Brimblecombe and Grossi, 2009), quality of drinking water (Hu et al., 2010), climate change (Li et al., 2011) and

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aerosol research (Xie et al., 2008). Other studies treat the academic output in environmental sciences altogether, but focus on certain geographic areas (Acosta et al., 2009 for Europe) or even on a specific country (Karki, 1990 for India).

Our study investigates the assumption that both research and environment protection are priority issues for developed countries. The reasoning shows that the government decisions supporting environment programmes can also be decisive in promoting academic output. As shown by bibliometric empirical studies, the research is correlated almost exclusively with the financing level. However, the mechanism by which a good quality of the environment can be obtained in a country is much more complex. The main factors that influence the environmental performance are often analysed in publications:

- unequal distribution of incomes as measured by a Gini index coefficient — Boyce (1994), Boyce et al. (1999), Maganani (2000), Gawande et al. (2001) and Bimonte (2002);
- accumulation of human capital, ecological behaviour and education expenses — Brasington and Hite (2005), Yang et al. (2011), and Dinu (2012);
- population and population density — Cronshaw and Requate (1997), and Harte (2007);
- structure of sectors within the economy — Arrow et al. (1995), and Eriksson and Persoon (2003);
- government policies for sustaining the environment — Juntti et al. (2009), Garau et al. (2011), and Moghimi and Alambeigi (2012).

If the existence of the mechanisms highlighted in our study is proved, it immediately follows that these mentioned factors affect decisively the academic output in environmental sciences and ecology.

2. Materials and methods

The data sample includes 92 countries and for each all the variables are available. Data is collected from:

- Essential Science Indicators (Web of Knowledge) — the number of articles and citations in journals indexed by Thomson ISI for each country;
- World Development Indicators (World Bank, 2012) for economic and demographic variables;
- Yale University for Environmental Performance Index.

We use the following variables in regressions:

PPP_i publication per population. It represents the number of articles in *Environmental Sciences and Ecology* published by country *i* in journals indexed by Thomson ISI between January 1st, 2008 and June 30th, 2012 in reference to 1 million inhabitants. In the literature, there are some journals with a significant contribution, like *Ecology* or *Water*, that are not indexed by Thomson ISI. Nevertheless, their contribution, expressed as the total number of articles published, is insignificant compared to the total number of articles published in the 322 journals considered. Furthermore, the proportion of each country's contribution is approximately the same as the one from the journals indexed by Thomson ISI. As a consequence, including other journals into the study would not change the results significantly. For this reason and because of their accuracy too, we will use the data published by Thomson ISI;

CPP_i citation per population. The number of citations accumulated by the researchers in a country in Thomson ISI journals between January 1st, 2008 and June 30th, 2012 again in reference to 1 million inhabitants;

EPI_i Environmental Performance Index (2010). It is a composed index computed by researchers from Yale University (2010). The following aspects regarding the environmental quality were considered: environmental burden of disease (25%), climate change (25%), air pollution (effects on humans 12.5%, effects on ecosystem 4.167%), water (effects on humans 12.5%, effects on ecosystem 4.167%), biodiversity and habitat (4.167%), forestry (4.167%), fisheries (4.167%), and agriculture (4.167%);

$ExpEDUC_i$ expenditure on education per capita ($). Results of our computations using public spending on education (% of GDP) and GDP per capita ($) — World Bank, 2012. We used average values for the 2006–2009 period, mainly because of a usual delay between investment in education and the academic output;

ISI_DUMMY_i dummy variable; ISI_DUMMY = 1 if country *i* edits at least one journal indexed by Thomson ISI; ISI_DUMMY = 0 if otherwise. All categories from *Environmental Sciences and Ecology* field were considered;

DOM_JOURN_i domestic journals. Number of published journals in the 2008–2012 period in country *i* related to 1 million inhabitants. All the journals indexed by Thomson ISI in *Environmental Sciences and Ecology* field were taken into consideration;

DOM_ARTIC_i domestic articles. Number of articles published in the 2008–2012 period by the journals corresponding to the variable DOM_JOURN_i;

$ENGL_i$ dummy variable; $ENGL_i = 1$ if English is the official language; $ENGL_i = 0$ if otherwise. In some countries, in which English coexists as an official language or is employed in the educational system we use $ENGL_i = 0.5$.

The research methodology uses OLS Multiple Regression with PPP as the endogenous variable. The other variables characterizing agricultural, technical and economic potential of the countries in the representative sample are considered exogenous.

3. Results and discussion

Some bibliometric studies across countries consider two dimensions of the academic output: a quantitative and a qualitative one (Davarpanah, 2010; Nejati and Hosseini Jenab, 2010). The quantitative dimension is measured generally by the total number of published articles, the number of articles related to population, the growth rate of the number of articles etc. The qualitative dimension is measured by the same type of indicators, but with reference to the number of citations, or by the average number of citations related to an article. The scientific performance is evaluated using cluster analysis, identifying three types regarding the publishing behaviour. In environmental sciences and ecology, the two dimensions are strongly correlated: $R^2 = 0.959$ (see Fig. 1). This finding allows a bibliometric analysis of the sample countries, considering as an endogenous variable only *Publication per population* (PPP). The replacement of PPP with the variable CPP does not affect the mechanisms highlighted in this article.

The results of the regressions are given in Table 1. Overall, the variables EPI, ExpEDUC and ENGLISH are highly statistically significant regardless of the specifications chosen for the function. The positive signs show their direct correlation with the number of published articles. For the influence of the domestic journals we have chosen four different specifications, but none is conclusive. The best specification indicates a correlation with the square rooted number of domestic journals (equation 2). In general, if a country increases the number of its domestic journals, the proportion of local authors diminishes. Thus, the correlation with PPP is not linear. The use of other two explicative variables Sqrt_DOM_ARTIC and ISI_DUMMY (equations 3 and 4) leads to even less relevant results. Some countries with smaller contribution (Bulgaria, Greece, Iran, Poland, Venezuela, etc.) edit their own independent journals where they publish mainly local authors. For these countries, the existence of domestic journals influences significantly the number of published articles. However, at a global level, these variables are not significant because the

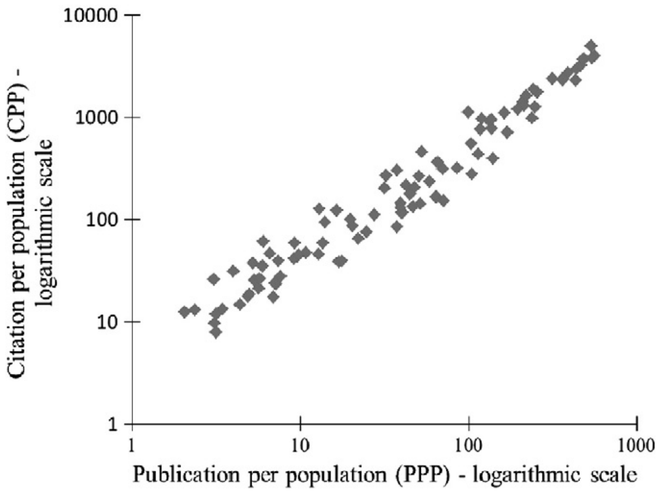

Fig. 1. Quantity and quality of academic output in environmental sciences and ecology.

majority of the articles published in *Environmental Sciences and Ecology* are edited by few big publishing groups (Elsevier, Springer, WileyBlackwell, Taylor & Francis). However, these specifications and their results are beyond the scope of our study and the factors introduced in the model play only the role of control variables. Moreover, these factors are not specific for environmental sciences & ecology, they are generally valid for any research domain.

More interesting and specific is the debate concerning the role of the Environmental Performance Index (EPI) factor. The role of a clean and ecological environment in the motivation of research in this area is demonstrated through the regressions. A discussion of the values detected in the sample can identify some behavioural models (Fig. 2). The acronym of the World Bank is used for each country and the corresponding country name is listed in Table 2. The axes discriminate the countries from the sample, crossing in the point of coordinates (62, 106) which represents the average values of the two variables. Fig. 3 offers a more detailed image of the countries with a PPP value below the average. Thus, four groups with distinct behaviour can emerge:

- In group A we have the countries with good and excellent quality of the environment and with an above average scientific performance. Generally, we refer to countries from Northern Europe (plus Australia, New Zealand and Canada) with very high incomes and a relatively small population. Both in the academic and governmental areas, their concerns about the environment are not recent.
- In group B we find countries with an environmental quality above average and with an academic output around or slightly over the mean. The incomes are usually high, but rather heterogeneous. The population and its density present a great variation as well. Geographically we notice countries from all continents, mainly from Europe.
- In group C, environment quality is acceptable, around the mean, but the bibliometric indicators have lower performance. We notice the presence of several countries with an ancient history and culture (Egypt, Iran, Jordan, Korea, Lebanon, Mexico, Russia, Turkey, etc.) whose populations and governments are only partially preoccupied with environmental problems. The present financial resources will not allow them to achieve remarkable performance in the scientific research. However, the situation can change fundamentally in a few years, mainly due to their above average economic growth.
- In group D, the two variables have low values. The majority of the countries are very poor, with high population and high population density (Ethiopia, India, Indonesia, Kenya, Nigeria, Pakistan, Uganda, etc.). By contrast, the United Arab Emirates, Oman, Kuwait or China has enough financial resources to classify much better. In these cases it can be the effect of deficient governmental policies concerning the environment and the related academic research.
- Outliers. Some countries are difficult to categorise since they do not seem to harmonise with any of the behavioural types. Belgium's position is atypical; the quadrant in which it is situated is almost empty. Belgium manages to produce pertinent academic output, but has a below average value for environmental performance. Also Japan's position is surprising because with consistent financial resources it does not produce a scientific output similar to other fields of research. Colombia, Cuba and especially Costa Rica are also occupying unusual positions. They are ranked among the best performers in environment quality; still, the number of published articles is rather small. The causes reside in an unsatisfactory development of higher education system and a low level of research expenditures.

Table 1
Coefficients of OLS regressions (t-values between parentheses).

PPP	Equation 1	Equation 2	Equation 3	Equation 4
EPI	2.349*** (2.84)	2.262*** (2.75)	2.347*** (2.84)	2.315*** (2.80)
ExpEDUC	0.089*** (9.97)	0.086*** (9.20)	0.089*** (9.90)	0.089*** (10.4)
DOM_JOURN	1.794 (0.59)	–	–	–
Sqrt_DOM_JOURN	–	14.82 (1.27)	–	–
Sqrt_DOM_ARTIC	–	–	0.657 (0.44)	–
ISI_DUMMY	–	–	–	13.40** (0.75)
ENGLISH	63.28** (2.42)	56.39** (2.13)	63.98** (2.43)	63.27 (2.45)
Constant	−130.6*** (−2.65)	−126.1** (−2.57)	−130.9*** (−2.65)	−131.7*** (−2.68)
	$R^2=0.748$	$R^2=0.752$	$R^2=0.748$	$R^2=0.737$
	N=92	N=92	N=92	N=92

***, **, * Significant at 1%, 5% and 10% level.
Source: authors' computations using STATA 9.1 software.

In Table 2 we give a ranking of the countries regarding environmental preoccupations. R_{EPI} is the rank according to Environmental Performance Index, and R_{PPP} is the rank according to the number of articles per 1 million inhabitants. The rank of each country (R) equally takes into consideration R_{EPI} and $R_{PPP.}$ The Spearman correlation coefficient between R_{EPI} and R_{PPP} is 0.609. Apparently, the correlation is done only by the mean of the finance capacities, most developed countries spending more money on both environmental protection and research. In fact, one can notice some surprising situations, the USA being ranked between Hungary and Romania. Also, some oil exporting countries like Kuwait, Saudi Arabia, Oman, and the United Arab Emirates, hold positions in the last third of the ranking. Even though financing is the main factor (Spearman correlation coefficient between R and GDP per capita is 0.726), the concern about the environment is a much more complex mechanism, in which the human capital is also involved.

We notice huge differences concerning population income between the countries that dominate the classification and those occupying the last positions. During the analysed period (2006–2009), the first ten states have an average GDP per capita of $48,150 unlike the last ten which have only $850. The same discrepancy is found with regard to the population, from 11.8 million (the average of top ten countries) to 210 million inhabitants (the average of the last ten countries). Following the regression results, these factors implicitly become explanatory variables for the scientific productivity too.

4. Conclusions

Focusing on the academic output from environmental sciences and ecology, the article confirms the results of some previous studies concerning the relevant explanatory variables: education financing,

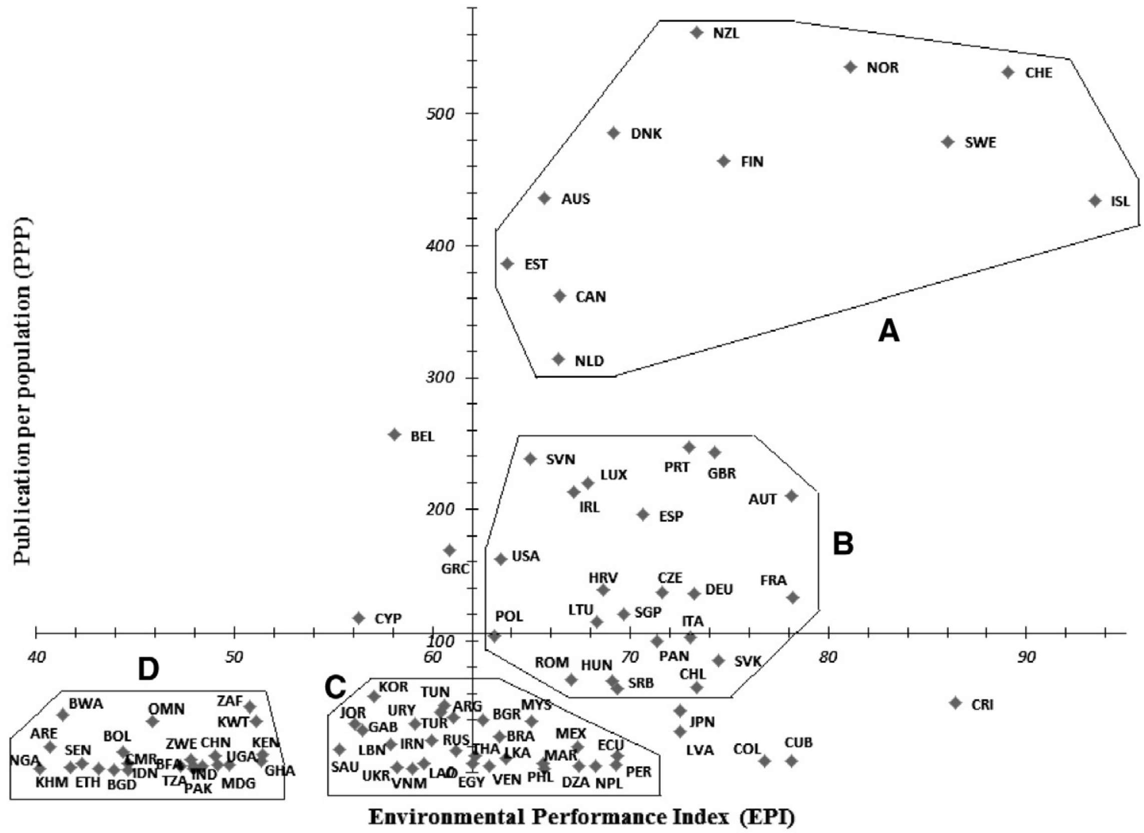

Fig. 2. Distribution of countries by EPI and PPP.

publishing of domestic journals and the English language. In addition, we found another specific factor for this field in the environmental quality of a country. Although there is a complex causality relation, the main direction in which the correlation works can be identified by disposing the variables in a Cartesian coordinate system. The quadrant in which the Environmental Performance Index is above

Table 2
Ranking of countries by environmental preoccupations.

R	Country	R_{EPI}	R_{PPP}	R	Country	R_{EPI}	R_{PPP}	R	Country	R_{EPI}	R_{PPP}
1	Switzerland (CHE)	2	3	32	Hungary (HUN)	28	34	63	Kuwait (KWT)	72	46
2	Norway (NOR)	5	2	33	USA (USA)	46	21	64	Lebanon (LBN)	64	55
3	Iceland (ISL)	1	8	34	Romania (ROM)	36	33	65	Egypt (EGY)	52	72
3	Sweden (SWE)	4	5	35	Latvia (LVA)	19	52	66	S Arabia (SAU)	69	58
5	N Zealand (NZL)	13	1	36	Cuba (CUB)	7	67	67	Philippines (PHL)	39	90
6	Finland (FIN)	10	6	37	Greece (GRC)	55	20	67	Laos (LAO)	59	70
7	Austria (AUT)	7	18	37	Belgium (BEL)	63	12	69	Venezuela (VEN)	49	81
8	U Kingdom (GBR)	12	14	39	Colombia (COL)	9	68	69	Oman (OMN)	82	48
9	Portugal (PRT)	17	13	39	Poland (POL)	48	29	71	Kenya (KEN)	70	61
10	Denmark (DNK)	27	4	41	Ecuador (ECU)	25	63	72	Botswana (BWA)	90	43
10	France (FRA)	6	25	42	Malaysia (MYS)	42	47	73	China (CHN)	76	62
12	Germany (GER)	15	24	43	Mexico (MEX)	34	56	74	Ghana (GHA)	71	69
13	Costa Rica (CRI)	3	38	44	Cyprus (CYP)	67	27	75	Bolivia (BOL)	85	60
13	Spain (ESP)	22	19	45	Bulgaria (BGR)	50	45	76	Ukraine (UKR)	62	84
15	Slovakia (SVK)	11	32	45	Tunisia (TUN)	56	39	76	Zimbabwe (ZWE)	80	66
15	Czech Rep (CZE)	20	23	47	Argentina (ARG)	54	44	78	Vietnam (VNM)	61	86
17	Italy (ITA)	16	30	48	Turkey (TUR)	57	42	79	UA Emir. (ARE)	91	57
18	Canada (CAN)	37	10	49	Brazil (BRA)	47	53	80	Uganda (UGA)	74	77
18	Australia (AUS)	40	7	50	Peru (PER)	26	75	80	Madagascar (MDG)	75	76
20	Luxembou. (LUX)	32	16	51	S Korea (KOR)	65	37	82	Cameroon (CMR)	83	71
21	Chile (CHL)	14	35	52	Sri Lanka (LKA)	45	65	83	Tanzania (TZA)	79	78
21	Singapore (SGP)	23	26	52	Uruguay (URY)	60	50	84	India (IND)	77	83
21	Netherlands (NLD)	38	11	54	Algeria (DZA)	33	79	85	Burkina F. (BFA)	81	80
24	Croatia (HRV)	29	22	54	Russia (RUS)	53	59	85	Senegal (SEN)	88	73
25	Panama (PAN)	21	31	54	Iran (IRN)	58	54	87	Pakistan (PAK)	78	88
25	Ireland (IRL)	35	17	57	Nepal (NPL)	31	82	88	Cambodia (KHM)	89	85
27	Estonia (EST)	44	9	57	S Africa (ZAF)	73	40	89	Indonesia (IDN)	84	92
28	Lithuania (LTU)	30	28	59	Morocco (MAR)	41	74	89	Ethiopia (ETH)	87	89
28	Slovenia (SVN)	43	15	59	Thailand (THA)	51	64	91	Bangladesh (BGD)	86	91
30	Japan (JPN)	18	41	61	Gabon (GAB)	66	51	92	Nigeria (NGA)	92	87
31	Serbia (SRB)	24	36	61	Jordan (JOR)	68	49				

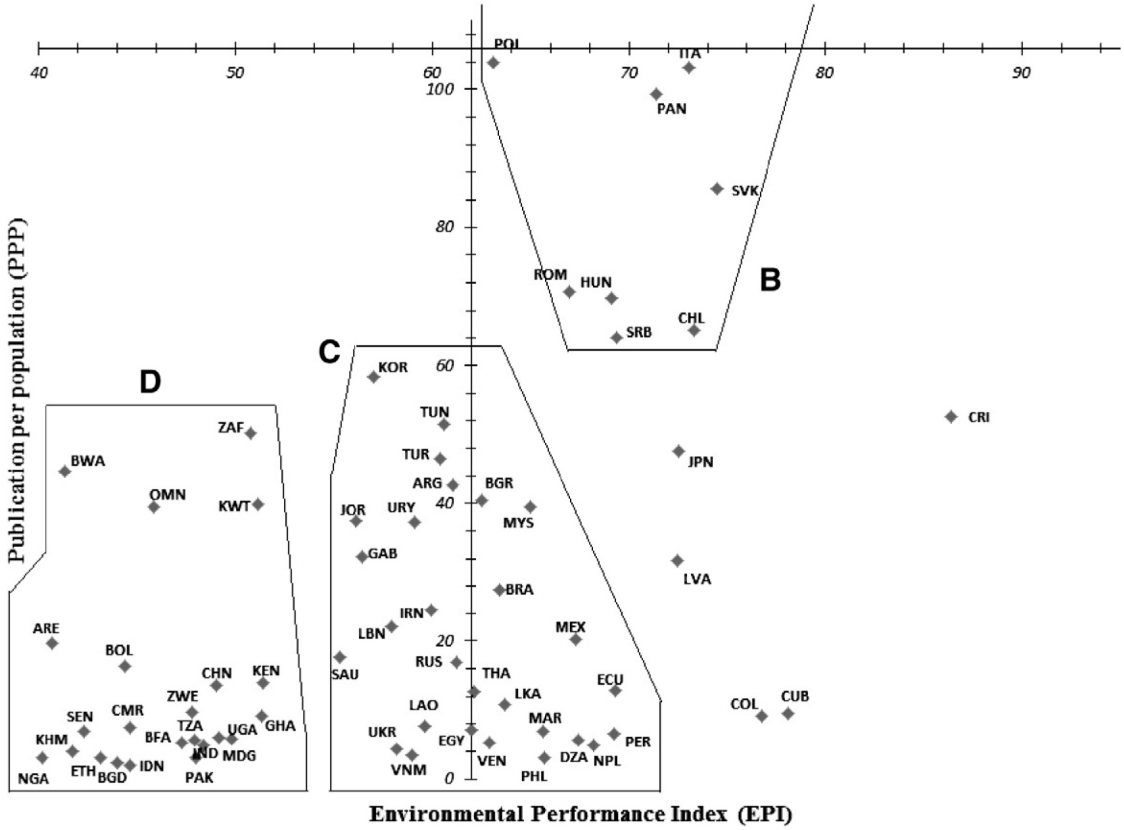

Fig. 3. Distribution of countries (with a below average value of PPP) by EPI and PPP.

average and the scientific productivity is below average contains 28% of the countries in the sample. In return, the opposite quadrant is almost empty.

Therefore, we cannot expect a relevant academic output from the countries that do not have adequate governmental politics and population self-awareness. The lack of incentives to produce specific academic output can be only partially compensated by governmental spending on education.

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