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A Comprehensive Approach to Measuring the Multidimensional Productivity Index: A Reiteration of Global Productivity Convergence

Md Harun Or Rosid, Zhao Xuefeng, Reajmin Sultana, Najmul Hasan

Abstract

The undeniable significance of production has prompted experts to explore further the competitive productivity of various nations across the globe. Despite the importance of global productivity competitiveness, prior studies have not included a comprehensive assessment of the multidimensional productivity index (MPI). Therefore, this study aims to achieve two objectives. First, it extends the scope of prior studies by integrating capital as an input alongside labor and energy consumption, based on 50 factors under 11 indices (including democracy, global competitiveness, and innovation index). Second, global competitive productivity convergence is reaffirmed and expanded. This study employed secondary panel data from 2007 to 2018, and 60,000 data points were obtained from 100 nations. The results reveal that the USA is the most productive country, followed by China, India, and Japan in the context of global competitive productivity. Regional productivity scores show that Asia has a superior productivity rank compared to Europe. However, Africa is performing worse than average. Unlike earlier studies, this study shows that macroeconomic, innovation and infrastructural variables mainly determine the MPI score. The main finding of this study is that there is no statistically significant difference in total factor productivity (TFP) among the developed, developing, and least developed countries. Also, there is no significant influence of regions or alliances on TFP across the countries, confirming the global convergence in competitive productivity. The novelty of this study is that certain statistical evidence accurately portrays global competitiveness in terms of productivity.

Keywords: total factor productivity, multidimensional productivity index, global competitive productivity, productivity convergence

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1. INTRODUCTION

Total factor productivity (TFP) is a metric for residual growth that cannot be clarified by changes in labor and capital services. Studies have established that TFP is an important source of cross-country differences in income levels and growth rates (Tamberi, 2020). Given this difference, energy inputs play different roles in production, and energy policy decision-making requires an evaluation of competitive productivity changes in individual energy inputs to provide insights into the scope for improvement in the utilization of specific energy inputs. Further, TFP changes are apparently sensitive to the choice of methodology. Nevertheless, the second-stage econometric analysis provides robust results. In a recent study, it has been verified which method of TFP provides the most consistent results, finding that the Woolridge method is the most robust and contemporary technique for competitive productivity estimation, followed by the ACF (Ackerberg, Caves, & Frazer) (Mollisi & Rovigatti, 2017) and LP (Levinsohn–Petrin) (Zhang & Tian, 2020) models. Rath & Akram's (2019) study, alongside others, has shown how global convergence in competitive productivity is taking place. These authors analyzed the productivity of countries in different regions and their income, but omitted the least developed countries from their study. Further, measuring TFP based on labor and energy consumption ignores the role of capital (Kim et al., 2018). Another study showed the necessity of alliance-based TFP by analyzing the productivity strengths of OPEC countries. A comprehensive study on TFP, including capital inputs and the least developed countries, along with different alliances, is therefore required.

The remainder of the article is organized as follows. The theoretical background is described in Section 2. Section 3 discusses the research objective, the methodological approach, and the data utilized. The results are presented and discussed in Section 4. Finally, conclusions, limitations, and directions for further study are presented in Section 5.

2. THEORETICAL BACKGROUND

TFP is a valuable tool for policymakers because it is a critical indicator of performance. However, due to the lack of homogeneous data sources, research comparing TFP output using micro-level data across countries has been minimal. Recent research across 69 developed countries included factors such as exporting, creativity, access to finance, foreign ownership, and regulations (Şeker & Saliola, 2018). Another recent empirical study focused on a chronology of inclusive growth episodes for a sample of 78 countries from 1980 to 2013, adding to the policy debate concerning how countries should cope with trade-offs between productivity and equity (Jalles & Mello, 2019). Further studies have identified that multi-factor productivity (MFP) has no apparent dependence on most of the factors, except for tertiary education (Bilan et al., 2020). A study on African countries from 2009 to 2017 was carried out using the data envelopment analysis method, which found reasonable evidence in favor of R&D expenditure to achieve better results in growth and development (Dobrzanski et al., 2021).

Four major papers have been identified that have studied cross-country competitive productivity indices. The first paper, by Islam (2008), divided productivity determinants into four categories, namely economic, institutional, social, and physical factors. The relationships investigated and developed in the paper seem to be useful in the enhancement of a TFP theory (Islam, 2008). The second paper, by Loko & Diouf (2009), used principal component analysis and dynamic panel data to investigate the main determinants of TFP growth. The findings showed that reforms aimed at attracting foreign direct investment and rationalizing government size, as well as redistributing capital from low- to high-productivity sectors, could help to accelerate TFP gains. Reforms aimed at enhancing human resources, increasing trade volume, and improving the market climate are also critical (Loko & Diouf, 2009). The third paper, by Kim & Loayza (2017), described the five key determinants of economic productivity: innovation, education, consumer performance, physical infrastructure, and institutional infrastructure. These authors created indexes as a linear combination of representative indicators to reflect each key determinant and then assessed the relative contribution of the indexes to the variance in productivity across 65 countries from 1985 to 2011. They calculated the correlation between productivity growth and a determinant index. The findings showed that physical infrastructure has the greatest impact on growth, followed by education, business quality, innovation, and institutional infrastructure. The overall determinant index is related to productivity growth in a positive way. The fourth paper, by Kim et al. (2008), which serves as the foundation for the present research, set out to create a productivity index that considers the multidimensional characteristics of productivity. Their MPI assesses not only individual productivities of economic capital, but also productivity that improves the economy's overall ability. Individual productivity indexes, such as labor productivity, are limited because they do not account for factors such as economic globalization, business, and institutional variables, which can have a significant effect on productivity. Their approach is based on the principle of technological quality, which enabled them to assess the contribution of structural and market variables to economic growth. Standard productivity indicators, such as labor productivity, can overestimate overall productivity differences across economies, according to their findings (Kim et al., 2018). However, this study ignored capital as an input in the productivity calculation, which needs to be added in further research to ensure comprehensiveness and a deeper understanding of competitiveness. Between 2000 and 2012, performance, competitiveness, and convergence were assessed in 34 OECD countries. In the data envelopment analysis, physical capital and human capital per worker were used as inputs to calculate TFP and efficiency ratings, while GDP per worker was used as an output. Non-parametric approaches have shown that businesses that are more complicated and innovative are more efficient in OECD countries.

Convergence of TFPs has also been confirmed by regional findings (Africa, Asia, Latin America and the Caribbean), with the Phillips and Sul tests showing that TFP convergence is occurring, although the rate of convergence varies by region. The Asia region has the fastest productivity convergence, while the African region has the slowest (Rath & Akram, 2019). In this study, only 44 developing and 29 developed countries were considered. Therefore, adding more countries to test the reality of global competitive productivity convergence is essential. For this reason, the following hypotheses are proposed to test global productivity convergence based on more countries, including the least developed countries, to provide a comprehensive understanding. If convergence is a reality among the countries of the world, it is expected that there will be no significant differences in TFP among countries. Therefore, to test the authenticity of this convergence, we propose the following hypotheses:

H0: There is no significant difference in TFP among countries.

H1: There is a significant difference in TFP among developed, developing, and least developed countries.

H2: There is a significant impact of regions on the TFP of a nation.

H3: Trade and other alliances have a significant influence on the TFP of a nation.

3. RESEARCH OBJECTIVE, METHODOLOGY AND DATA

Based on the above theoretical overview and research gaps, the current study aims to achieve the following objectives: a) to develop a comprehensive multidimensional competitive productivity index by integrating capital as an input alongside labor and energy consumption, based on 50 factors and under 11 indices (including democracy, global competitiveness, and innovation index); and b) to reiterate global competitive productivity convergence. First, this study will complement the study of Kim et al. (2018) by adding capital input into the TFP calculation. Also, new countries will be added to the list to make it more comprehensive. New categories of variables will also be added to the existing MPI, alongside the four existing ones, to make the index more comprehensive. Furthermore, by including the least developed countries in the study, this study aims to reiterate and confirm Rath & Akram's (2019) claims regarding global productivity convergence. In addition, the effects of global trade and economic alliances on productivity will also be analyzed in the context of convergence.

3.1 Data

Secondary panel data were used in this research. A total of 60,000 data points were retrieved from 100 countries from 2007 to 2018 (12 years), with 50 variables. These data were collected from different sources: macroeconomic data were collected from the World Bank; economic freedom data were collected from the Economic Freedom Index; competitiveness data were collected from the Global Competitiveness Index, and data for democracy were collected from Gapminder.

3.2 Methodology

This research is quantitative, incorporating the notion of technical efficiency in the context of determining what factors contribute to the MPI. The application of extended variables may be used to obtain an understanding of how they function in terms of competitive productivity improvement. A four-stage analytical approach was deployed in this study to obtain the comprehensive TFP scores for the 100 countries under investigation. A detailed explanation of the analytical stages is provided in the following sub-sections.

3.2.1 First stage analysis: TFP estimation models and techniques

TFP is a measure of productivity calculated by dividing economy-wide total production by the weighted average of inputs, i.e., labor and capital. There are two measures of productivity: (a) labor productivity, which equals total output divided by the units of labor, and (b) TFP, which equals total output divided by the weighted average of the inputs. According to Jan (2019):

TFP=(Total Product viz.GDP)/(Weighted Average of Inputs (1)

The most widely used production function is the Cobb–Douglas function. The function is as follows:

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} E_{it}^{\beta_e} \quad (2)$$

where Y_{it} represents the physical output of country i in period t; K_{it}, L_{it}, and E_{it} are inputs of capital, labor, and energy consumption, respectively, and Ait is the Hicksian neutral efficiency level of country i in period t. If we rearrange the Cobb–Douglas function, we get the following formula for total factor productivity (TFP):

$$\text{TFP} = A_{it} = \frac{\text{Total Product}}{\text{Weighted Average of Inputs}} = \frac{Y_{it}}{K_{it}^{\beta_k} L_{it}^{\beta_l} E_{it}^{\beta_e}} \quad (3)$$

Here, TFP represents the increase in total production, which is in excess of the increase that results from the increase in inputs. The following growth accounting equation gives us the relationship between growth in total product, growth in labor and capital, and growth in TFP:

$$\frac{\Delta Y_{it}}{Y_{it}} = \beta_k \times \frac{\Delta K_{it}}{K_{it}} + \beta_l \times \frac{\Delta L_{it}}{L_{it}} + \beta_e \times \frac{\Delta E_{it}}{E_{it}} + \frac{\Delta A_{it}}{A_{it}} \quad (4)$$

While in Eq. (1), Y_{it}, K_{it}, L_{it}, and E_{it} are all observable, Ait is unobservable to the researcher. Taking natural logs of the results from Eq. (1) in a linear production function leads to the following:

$$\ln Y_{it} = \beta_0 + \beta_k lnK_{it} + \beta_l lnL_{it} + \beta_e lnE_{it} + \varepsilon_{it} \quad (5)$$

where $ln(A_{it})=\beta_0+\varepsilon_{it}$

Here, β_0 measures the mean efficiency level across countries and over time, and ε_{it} is the time and country-specific deviation from the mean, which can then be further decomposed into an observable (or at least predictable) and an unobservable component. This results in the following equation, which will serve as the starting point for the remainder of this and the following sub-sections:

$$Y_{it} = \beta_0 + \beta_k K_{it} + \beta_l L_{it} + \beta_e E_{it} + \omega_{it} + u_{it} \quad (6)$$

where ω_{it} represents country-level productivity and uit is an independent and identically distributed (IID) component, representing unexpected deviations from the mean due to measurement error, unexpected delays, or other external circumstances.

Typically, empirical researchers estimate Eq. (6) to resolve ω_{it}. Estimated productivity can then be calculated as follows:

$$\widehat{\omega_{it}} = Y_{it} - \beta_k K_{it} - \beta_l L_{it} - \beta_e E_{it} \quad (7)$$

Subsequently, productivity in levels can be obtained as the exponential of $\widehat{\omega_{it}}$, i.e. $\widehat{\omega_{it}}$, i.e. $\widehat{\Omega_{it}} = \widehat{\exp(\widehat{\omega_{it}})}$. The productivity measure resulting from Eq. (7) can be used to evaluate the influence and impact of various policy variables directly at the country level; alternatively, country-level TFP can be aggregated to the regional level by calculating the share-weighted average of $\widehat{\Omega_{it}}$.

3.2.2 Second stage analysis

The estimated TFP based on the above techniques was regressed through multiple variables based on the literature pertaining to productivity determinants, adopting a comprehensive approach considering all the studied and neglected variables. The overlapping error was carefully addressed and solved. Accordingly, the comprehensive index was regressed, taking 11 broad indices comprising 50 variables. The functional relationships among them are shown below (see Table 1 for an explanation of the variables):

MPI = f (MV, EFV, GCV, DV, IV, EV, MEV, INSTI, INFRA, SBV, PBV)

Tab. 1 – The variables under each category and the data source. Source: own research

Type	Variable	Description and source	Reference
Economic Freedom Variables (EFV)	GSA	Gross Savings Source: World Bank	(Chaudhri & Wilson, 2000)
	GS	Government Spending Source: World Bank	(Amusa & Oyinlola, 2019)
	GNEcu	Gross National Expenditure Source: World Bank	(Khan & Murova, 2015)
	MEusd	Military Expenditure Source: World Bank	(d'Agostino et al., 2018)
	HouseFCcu	Household Final consumption expenditure Source: World Bank	(Michaillat & Saez, 2019)
	BM	Broad Money Source: World Bank	(Chude & Chude, 2016)
	Im	Import Source: World Bank	(de Boyrie & Kreinin, 2013)
	NDC	Net Domestic Credit Source: World Bank	(Doerr et al., 2018)
	PRP	Personal Remittance Paid Source: World Bank	(Ghimire & Kapri, 2020; Makhlouf, 2019)
	PRR	Personal Remittance Received Source: World Bank	(Mamun et al., 2015)
Macroeconomic Variables (MV)	PR	Property rights Source: The Heritage Foundation	(Besley & Ghatak, 2010)
	TB	Tax Burden Source: The Heritage Foundation	(Poirson, 2006)
	IF	Investment Freedom Source: The Heritage Foundation	(Zghidi et al., 2016)
Global Competitiveness Variables (GCV)	Insti	Institutions Source: World Economic Forum	(Acemoglu et al., 2004)
	HPE	Health and Primary Education Source: World Economic Forum	(Samaranayake et al., 2017)

Global Competitiveness Variables (GCV)	HET	Higher Education and Training Source: World Economic Forum	(Abdalla Alfaki & Ahmed, 2013)
	TR	Technological Readiness Source: World Economic Forum	(Samaranayake et al., 2017)
	MS	Market Size Source: World Economic Forum	(Corsetti et al., 2007)
	BS	Business Sophistication Source: World Economic Forum	(Vesal et al., 2013)
Democracy Variables (DV)	GIN	Government Index Source: Gapminder	(Barber & Schmidt, 2019)
	PPI	Political Participation Index Source: Gapminder	(Keefer & Knack, 1997)
	PCI	Political Culture Index Source: Gapminder	(Jackman & Miller, 1996)
	CLI	Civil Liberties Index Source: Gapminder	(Anwar & Cooray, 2012)
Innovation Variables (IV)	RDcon	Research and Development Source: World Bank	(Aiello et al., 2019)
	Patenttotal	Number of Patents Source: World Bank	(Aboal et al., 2018)
	Journalarticle	Number of articles published Source: World Bank	(Crespi & Pianta, 2008)
	INV	Innovation Source: World Economic Forum	(Chudnovsky et al., 2006)
Educational Variables (EV)	EABachelor	Educational Attainment, Bachelor Source: World Bank	(Benhabib & Rustichini, 1996)
	EALS	Educational Attainment, Lower Secondary Source: World Bank	(Erosa et al., 2010)
	EAPS	Educational Attainment, Post-Secondary Source: World Bank	(Jorgenson & Fraumeni, 1993)
	EAPrimary	Educational Attainment, Primary Source: World Bank	(Abramo et al., 2011)
	EASTer	Educational Attainment, Short cycle Tertiary Source: World Bank	(Baharin et al., 2020)
	EAUS	Educational Attainment, Upper Secondary Source: World Bank	(Asuyama, 2019)
	EAMaster	Educational Attainment, Master Source: World Bank	(Grafton et al., 2007)
	EADoctor	Educational Attainment, Doctor Source: World Bank	(Tsang, 1987)
	ASEcugni	Adjusted savings: Education Expenditure Source: World Bank	(Neycheva, 2010)

Market Efficiency Variables (MEV)	GME	Goods market efficiency Source: World Economic Forum	(Radukic et al., 2019)
	LME	Labor market efficiency Source: World Economic Forum	(Kinfemichael, 2019)
Institutional Variables (INSTI)	Corruptioncpi	Corruption Source: Transparency International	(Bellavite Pellegrini et al., 2017)
	ROL	Rule of Law Source: World Bank	(Castelnovo et al., 2019)
	VandA	Voice and Accountability Source: World Bank	(Nadeem et al., 2020)
	Goveffe	Government Effectiveness Source: World Bank	(Masca et al., 2019)
	RQ	Regulatory Quality Source: World Bank	(Ghosal et al., 2019)
Infrastructural Variables (INFRA)	Raillineskm	Rail lines (Jackman & Miller)	(Cohen et al., 2019)
	SIS	Subsidies and other transfer Source: World Bank	(Domadenik et al., 2018)
	PUABDW	People using at least basic drinking water Source: World Bank	(Kulsum et al., 2020)
	PUABSS	People using at least basic sanitary services Source: World Bank	(Zhou & Turvey, 2018)
	Mobilep100	People using mobile phones Source: World Bank	(Li, 2009)
Social Base Variables (SBV)	EtnicFindex	Ethnic Fraction Index Source: World Bank	(Hamermesh et al., 2019)
Physical Base Variables (PBV)	AverageTemp	Average Temperature Source: World Bank	(Cerezer et al., 2020)
	Landlocked	Landlocked countries Source: World Bank	(Zidouemba & Gerard, 2018)

3.2.3 Third stage analysis

In the third stage, global productivity convergence reiteration based on the unit root test was ensured, including the use of a robust generalized method of moments (GMM). This robustness was confirmed via the Arellano–Bond, Sargan, and Hansen tests (Jóhannsson & Hansen, 2021). An endogeneity test was also performed to ensure that the data were exogenous.

3.2.4 Fourth stage analysis

In this stage, all the above variables were used to calculate the composite TFP score for each country. In the following sub-section, this calculation is explained.

3.5 TFP calculation

To ensure a solid foundation for the global productivity index, this study first measured the cross-country TFP score through the input–output-oriented Cobb–Douglas productivity function using GDP as output, and labor, capital, and energy consumption as inputs. Second, the TFP score was used as the dependent variable and all the 50 variables were used as independent variables. Subsequently, these sub-indices were given a weighted average score based on their coefficient of determination using multiple regression models. Next, the weighted average score based on the composite TFP score was computed for all the 100 countries to obtain the ranked results.

3.6 The construction of the MPI

The MPI was constructed as detailed in Table 2.

Tab. 2 – Overall weights used to calculate MPI through sub-indices. Source: own research

Model No.	(1) Category Name	(2) R^2 or Coefficient of Determination	(3) = Mi/(∑Mi) Weights
M1	MV	0.9404	0.2113
M2	EFV	0.1667	0.0374
M3	GCV	0.6522	0.1465
M4	DV	0.1134	0.0254
M5	IV	0.8952	0.2012
M6	EV	0.4167	0.0936
M7	MEV	0.1772	0.0398
M8	INSTIV	0.2159	0.0485
M9	INFRAV	0.7444	0.1672
M10	SBV	0.0085	0.0019
M11	PBV	0.1204	0.0270
Total		∑Mi= 4.451	1.0000

Table 2 was utilized with all the variables in each category to obtain categorical scores, which were then averaged together to provide a composite score for productivity. Given the inclusive nature of the calculation, the index is termed the MPI. This complements earlier studies, as well as adds new and more comprehensive variables.

3.6.1 MPI score calculation formula

The composite productivity score was calculated using the following formula:

$$\mathrm{MPI} = \sum_{1}^{11}(W_i \times C_i \times V_i) + \sum_{1}^{11}\left(\frac{W_i \times \alpha_i}{\sum W_i}\right) \quad (8)$$

where Wi is the weight of each model, C_i is the coefficient of each variable under each model, V_i is the variable's actual value under each model, and α is the constant value of each model. The application of the above equation is illustrated in supplementary documents available on request.

4. RESULTS AND DISCUSSION

4.1 Global comprehensive MPI

The MPI was calculated based on Eq. (8) and the results are presented in Table 3.

Tab. 3 – MPI scores of countries. Source: own research

Country	Total	Rank	Country	Total	Rank	Country	Total	Rank
United States	0.9349	1	Hong Kong SAR	0.8426	34	Panama	0.7978	67
China	0.9169	2	Switzerland	0.8425	35	Luxembourg	0.7972	68
Germany	0.9084	3	Austria	0.8423	36	Costa Rica	0.7970	69
India	0.8978	4	Greece	0.8412	37	Bolivia	0.7960	70
Russian Federation	0.8940	5	Sweden	0.8410	38	Slovenia	0.7945	71
Japan	0.8899	6	Kazakhstan	0.8381	39	Bahrain	0.7900	72
UK	0.8878	7	Czech Republic	0.8368	40	Paraguay	0.7896	73
Italy	0.8837	8	Portugal	0.8355	41	Uruguay	0.7857	74
France	0.8830	9	Vietnam	0.8354	42	Latvia	0.7852	75
Brazil	0.8789	10	Chile	0.8301	43	El Salvador	0.7812	76
Saudi Arabia	0.8775	11	Bangladesh	0.8297	44	Bosnia&Herz	0.7810	77
Turkey	0.8772	12	Algeria	0.8281	45	Cameroon	0.7805	78
Indonesia	0.8707	13	Hungary	0.8249	46	Georgia	0.7802	79
Spain	0.8689	14	Ireland	0.8249	47	Estonia	0.7797	80
Korea, Rep.	0.8674	15	Israel	0.8244	48	Nepal	0.7793	81
Egypt	0.8666	16	Denmark	0.8236	49	Cambodia	0.7765	82
Canada	0.8663	17	Kuwait	0.8231	50	Moldova	0.7711	83
Argentina	0.8603	18	Peru	0.8207	51	Zimbabwe	0.7707	84
Poland	0.8597	19	Norway	0.8196	52	Albania	0.7703	85
Thailand	0.8592	20	Finland	0.8185	53	Cyprus	0.7699	86
Netherlands	0.8582	21	Sri Lanka	0.8150	54	Armenia	0.7679	87
Pakistan	0.8570	22	Qatar	0.8148	55	Botswana	0.7650	88
Australia	0.8565	23	Bulgaria	0.8143	56	Senegal	0.7646	89
Malaysia	0.8547	24	New Zealand	0.8121	57	Mauritius	0.7641	90
Nigeria	0.8530	25	Morocco	0.8092	58	Jamaica	0.7606	91
Ukraine	0.8529	26	Slovak Rep.	0.8081	59	Nicaragua	0.7589	92
South Africa	0.8512	27	Ecuador	0.8061	60	Kyrgyz Rep.	0.7544	93
UAE	0.8508	28	Azerbaijan	0.8044	61	Benin	0.7456	94
Philippines	0.8495	29	Kenya	0.8030	62	Mongolia	0.7275	95
Singapore	0.8481	30	Serbia	0.8021	63	Malta	0.7225	96
Belgium	0.8479	31	Croatia	0.8017	64	Namibia	0.7061	97
Colombia	0.8472	32	Jordan	0.8002	65	Iceland	0.7016	98
Romania	0.8448	33	Lithuania	0.7998	66	Montenegro	0.6917	99
						Mozambique	0.5427	100

All the MPI scores and their respective ranks are shown in Table 3. According to Table 3, the United States of America (93.49%) is the most productive country in the world, followed by China (91.69%), Germany (90.84%), and India (89.78%). Mozambique (54.27%), Montenegro (69.17%), and Iceland (70.16%) are the countries at the bottom of the ranking. Overall, Table 3 shows the Wooldridge-method-based TFPs leading to MPI scores. The Asian region shows more productivity compared to the European and Australian regions. The Middle Eastern region lags in productivity compared to the other countries studied. South American countries are experiencing moderate growth, except for Brazil, which shows significant productivity. North American countries are also showing good productivity scores. Overall, average productivity is not dissatisfactory for the 100 nations studies, as the lowest country score is c. 54%. Therefore, the world is showing a good productivity cycle, despite the different factors among these nations.

The results of this research demonstrate that the approach for estimating an MPI may be used to measure productivity. In terms of competitive productivity, the findings demonstrate that varying degrees of MPI exists across the 100 nations that were analyzed. This is a substantial addition to current MPI research, offering a distinct advantage over other techniques in terms of accuracy.

4.2 World productivity trends with respect to labor, capital, and energy consumption

The general trend of TFP shows a steady-state growth alongside labor force, capital, and energy consumption (Figure 1) between 2007 to 2018. Productivity goes up when there is a great deal of work to go around. However, the scenario is different in the context of capital; the link between productivity and capital seems to be erratic. Despite the fact that energy consumption has been steadily increasing in productivity, there has been a significantly larger variation in productivity across nations. In general, productivity has been about 15.9 points each year over the years studied, with overall productivity for each year being relatively similar. An apparent divergence in the trajectory of labor, capital, and energy consumption may be seen if we compare the three factors. Additionally, it is noteworthy that capital, labor, and energy are consistently greater than the conventional measures, with only a small variation among nations. Historically, increases in worker productivity (which is simply a measure of how effectively individuals do things) have been fueled by technological advancements, improved education, increased capital formation, and improvements in labor productivity, which are considered key to achieving sustained long-term economic development.

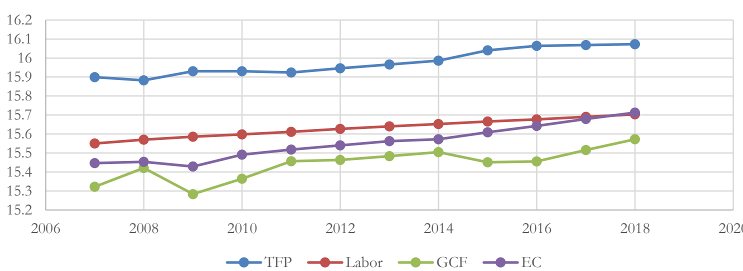

Fig. 1 – TFP trends alongside labor, capital, and energy consumption. Source: own research

4.3 Robustness of the models

Using the Sargan test (Ngo et al., 2020), Table 4 reveals that the residuals of Model 1 are not associated with the instrumental variable (Ghosal et al., 2019). In addition, the Hansen test (Jóhannsson & Hansen, 2021) supports the null hypothesis of instrument validity ($p<0.05$), suggesting that the instruments are exogenous and appropriate. Moreover, the model is free from second-order correlation, indicating no serial correlation. Also, the Arellano–Bond tests (AR1 and AR2) (Cheng & Bang, 2021) show negligible values, indicating no autocorrelation. Therefore, the overall model is valid and the relevant hypotheses are valid. Based on the unit root test and endogeneity test, all the above variables are stationary and exogenous.

Tab. 4 – Robustness of the models used to calculate MPI. Source: own research

Model No.	Category Name	(2) R^2 or Coefficient of Determination	Generalized Method of Moments (GMM) Model Test Results				Unit Root Test/ Granger Causality	Endogeneity Test	
			AR1 Statistics	AR2 Statistics	Sargan Statistics	Hansen Statistics		Durbin Chi²Score	Wu-Hausman (F)
M1	MV	0.9404	.175	.488	.144	.570	Levin-Lin-Chu unit-root test for TFProb: Ho: Panels contain unit roots Ha: Panels are stationary Adjusted t* = -4.7864, P value = .000	1.96908	1.89811
M2	EFV	0.1667	.163	.027	.00	.00		.74392	.73637
M3	GCV	0.6522	.00	.017	.00	.002		1.32735	1.31759
M4	DV	0.1134	.213	.813	.00	.00		1.85816	1.84776
M5	IV	0.8952	.008	.015	.00	.00		.314176	.311049
M6	EV	0.4167	.593	.264	.993	.981		2.45325	1.9989
M7	MEV	0.1772	.001	.628	.00	.00		2.16193	2.15041
M8	INSTIV	0.2159	.014	.289	.00	.00		.360036	.355898
M9	INFRAV	0.7444	.306	.806	.00	.003		2.10476	2.07662
M10	SBV	0.0085	.545	.239	.00	.00		-	-
M11	PBV	0.1204	.482	.105	.00	.00		-	-
Total		∑Mi= 4.451							

4.4 Developed vs. developing vs. least developed countries and MPI results

To assess this, we arranged the MPI according to developed, developing, and least developed countries (see Table 5) (Desa, 2021).

Tab. 5 – MPI according to region. Source: own research

Country	MV	EFV	GCV	DV	IV	EV	MEV	INSTI	INFRA	SBV	PBV	Explain	Const.	TFP	Rank
Developed	0.126	-0.003	0.022	-0.001	0.071	0.001	0.003	-0.002	0.048	0	0	0.266	0.559	0.825	45
Developing	0.123	-0.003	0.021	0	0.066	0	0.003	-0.002	0.041	0	-0.001	0.248	0.559	0.807	56
LDC	0.087	-0.003	0.016	-0.001	0.051	0.001	0.003	-0.002	0.03	0	-0.001	0.181	0.559	0.74	82

Note: Country-wise detailed results are available on request.

Let us first look at the summary statistics and the kernel density chart for MPI to choose the appropriate method to test the null hypothesis. The mean and standard deviation are 0.817 and 0.055, respectively, while the range of the findings is between 0.543 and 0.935. Based on the kernel density, it is appropriate to use the normal distribution to test the hypothesis. The calculation of the z score is shown in Table 6 to enable conclusions to be drawn regarding the hypothesis concerning developed, developing, and least developed countries.

Tab. 6 – Calculation of the z score for developed, developing, and least developed countries. Source: own research

Developed Countries	Developing Countries	Least Developed Countries
$Z = \frac{x_i - \mu}{\sigma}, Z = \frac{.825 - .817}{.055}$ $Z = .1454$ Which is less than the critical value of 1.96 (α=5%). So, we accept the null hypothesis.	$Z = \frac{x_i - \mu}{\sigma}, Z = \frac{.807 - .817}{.055}$ $Z = .1818$ Which is less than the critical value of 1.96 (α=5%). So, we accept the null hypothesis.	$Z = \frac{x_i - \mu}{\sigma}, Z = \frac{.74 - .817}{.055}$ $Z = 1.4$ Which is less than the critical value of 1.96 (α=5%). So, we accept the null hypothesis.

We can see that developed countries have a higher productivity score (0.825) and rank (45) than developing and least developed countries [productivity scores of 0.807 and 0.74, and ranks of 56 and 82, respectively (significant at the 5% level)]. This sufficiently accepts the null hypothesis. This result strongly suggests that global convergence has taken place to create parity in productivity among the countries, irrespective of their status. It must be clarified here that there are differences in productivity volume and capacity among the countries, but there is parity in terms of TFP. Accordingly, H1 is supported. Broadly speaking, the MPI of the least developed nations, including the workforce ratio and the degree of poverty, is greater than in the developed world. Aside from that, developing countries are attempting to achieve the same economic well-being, healthcare, literacy, and lifestyles as individuals in rich economies.

4.5 Region-wise average MPI results

Region-wise MPI scores are presented in Table 7 and described in detail in this section.

Tab. 7 – Regional productivity average. Source: own research

Region	MV	EFV	GCV	DV	IV	EV	MEV	INSTI	INFRA	SBV	PBV	Expla.	Const	TFP	Rank
Asia	0.131	-0.003	0.023	0.0	0.072	0.003	0.003	-0.002	0.046	0.0	0.0	0.272	0.559	0.831	43
Europe	0.125	-0.003	0.021	-0.001	0.069	0.001	0.003	-0.002	0.044	0.0	-0.001	0.258	0.559	0.817	51
Africa	0.109	-0.003	0.02	-0.001	0.054	-0.002	0.003	-0.002	0.038	0.0	-0.001	0.216	0.559	0.775	68
Australia	0.127	-0.003	0.022	-0.001	0.073	0.002	0.004	-0.003	0.056	0.0	-0.001	0.275	0.559	0.834	40
S. Americ	0.129	-0.003	0.022	0.0	0.072	0.0	0.003	-0.002	0.045	0.0	-0.001	0.265	0.559	0.824	48
N. Americ	0.127	-0.003	0.021	-0.001	0.068	0.001	0.003	-0.003	0.041	0.0	0.0	0.255	0.559	0.814	59

Note: Country-wise detailed results are available on request.

The rank for Asia is 43, indicating a slightly better productivity position. It can also be seen that macroeconomic variables have the most influence on the scores for all the countries, followed by innovation variables and infrastructural variables. The productivity for Asia is 83.1%, while the productivity for Europe is 81.7%. The rank for Africa is 68, which is relatively high, indicating that Africa is a low productive region; the productivity for Africa is 77.5%. However, the rank for Australia and Oceania is 40, which is lower than average, indicating that Australia is a more productive region. A robust regression model could not be run due to the small number of countries in the region. The productivity for Australia and Oceania is 83.4%. It is worth noting that the rank for South America is 48, which is close to the global average, indicating that South

America is an average productive region. The productivity of South America is 82.4%. The rank for North America is 59, which is fairly high, indicating that North America is also a moderately low productive region (81.4%). It is commonly observed here that macroeconomic variables have the most influence on the scores for all the regions, followed by innovation variables (Ghosal et al., 2019) and infrastructural variables. Region-wise MPI again supports the null hypothesis. As in the previous hypothesis test, we used the normal distribution and z score to test the hypothesis. The hypothesis was supported for all the regions. As H2 is supported, the null hypothesis is accepted, suggesting that there is no difference in TFP among the countries of the world and that there is strong global convergence in productivity.

The above conclusion is also supported to a certain extent by the study of Zaher et al. (2010), in which productive efficiency and factors affecting it in 11 countries in the Middle East and North Africa region were evaluated over the period 1980 to 1999 using Fare's nonparametric approach. The results indicated that oil-producing countries are more efficient in terms of production compared with non-oil-producing countries. Tobit's analyses indicated that previous levels of efficiency, the degree of economic openness, consumption of domestically produced goods, and the limited availability of credit have a positive impact on production efficiency. A sensitivity analysis using the bias-corrected bootstrap technique showed that allocative efficiency and economic efficiency are more sensitive to the returns to scale assumption and sample size than pure technical efficiency (Zaher & Featherstone, 2010).

4.6 Global-alliance-wise average MPI results

To further analyze global convergence in productivity, alliance-based MPI scores are presented in Table 8 and detailed in this sub-section.

Tab. 8 – Alliance-wise productivity. Source: own research

Country	MV	EFV	GCV	DV	IV	EV	MEV	INSTI	INFRA	SBV	PBV	Expla.	Const	TFP	Rank
African U	0.109	-0.003	0.02	-0.001	0.054	-0.002	0.003	-0.002	0.038	0.0	-0.001	0.216	0.559	0.775	68
Arab Lea.	0.128	-0.003	0.023	0.0	0.075	0.0	0.004	-0.002	0.045	0.0	0.0	0.27	0.559	0.829	44
ASEAN	0.131	-0.002	0.023	0.0	0.073	0.007	0.004	-0.002	0.05	0.0	0.0	0.283	0.559	0.842	34
APEC	0.136	-0.003	0.026	0.0	0.078	0.005	0.003	-0.002	0.057	0.0	0.0	0.3	0.559	0.859	26
BIMSTEC	0.132	-0.003	0.024	0.0	0.076	0.002	0.003	-0.002	0.045	0.0	0.0	0.277	0.559	0.836	40
BRICS	0.143	-0.002	0.029	0.0	0.088	0.008	0.003	-0.001	0.062	0.0	0.0	0.329	0.559	0.888	10
BRI	0.123	-0.003	0.021	0.0	0.065	0.001	0.003	-0.002	0.042	0.0	-0.001	0.248	0.559	0.807	56
EU	0.128	-0.003	0.022	-0.001	0.072	0.001	0.003	-0.002	0.049	0.0	0.0	0.268	0.559	0.827	46
G20	0.143	-0.002	0.029	0.0	0.086	0.007	0.003	-0.002	0.062	0.0	0.0	0.325	0.559	0.884	10
WTO	0.125	-0.003	0.022	0.0	0.068	0.001	0.003	-0.002	0.044	0.0	-0.001	0.258	0.559	0.817	50
G7	0.146	-0.003	0.031	0.0	0.088	0.007	0.003	-0.002	0.064	0.0	0.0	0.334	0.559	0.893	7
NAFTA	0.148	-0.003	0.034	-0.001	0.09	0.005	0.003	-0.003	0.068	0.0	0.0	0.342	0.559	0.901	9
OECD	0.13	-0.003	0.024	-0.001	0.075	0.003	0.003	-0.002	0.052	0.0	0.0	0.28	0.559	0.839	38
OPEC	0.131	-0.002	0.024	0.0	0.075	0.004	0.003	-0.002	0.056	0.0	0.0	0.287	0.559	0.847	31
SAFTA	0.134	-0.004	0.024	0.0	0.076	0.003	0.003	-0.001	0.043	0.0	0.0	0.277	0.559	0.836	41

Note: Country-wise detailed results are available on request.

The rank for Arab League countries is 44, which is quite low, indicating that Arab League is a moderately high productive alliance. The productivity of the Arab League countries is 82.9%. The ASEAN rank is also quite low (34), indicating that ASEAN countries represent a moderately high productive alliance (productivity is 84.2%). APEC countries are ranked 26th, which is a considerably low position, with higher productivity (85.9%). However, the rank for BIMSTEC countries is 40, which is quite similar to that for APEC, indicating that BIMSTEC is a moderately high productive alliance (83.6%). On the other hand, the rank for BRICS countries is 10, indicating that BRICS is a very high productive alliance (88.8%). Furthermore, the rank for BRI (56), the EU (46), G20 (10), WTO (50), and G7 (7) are relatively close, with high productivity (80.7%, 87.7%, 88.4%, 81.7%, and 89.3%, respectively). Further, NAFTA (9), OECD (38), OPEC (31), SAFTA (41) are also ranked low, with relatively higher productivity (90.1%, 83.9%, 84.7%, and 83.6%, respectively).

It is commonly observed in regions that macroeconomic variables have the most influence on the score for all the alliances, followed by innovation variables (Ghosal et al., 2019) and infrastructural variables. Alliance-based MPI further supports the null hypothesis. We used the normal distribution and z score to test the hypothesis, as in the previous hypothesis test. All the alliances support the null hypotheses. As H3 is supported, the null hypothesis is accepted, suggesting that there is no difference in TFP among the world's countries and that there is strong global convergence in productivity. Overall, this study has investigated trends across and within nations, as well as MPI patterns, demonstrating a variety of approaches to achieve development.

5. CONCLUSION

In summary, this research has made some valuable contributions and insights. The comparative findings on regional productivity in terms of the MPI show that Asia (43) is superior (lower rank indicates higher productivity score) in terms of productivity rank compared to Europe (51), while Africa (68) is performing worse than average. South America (48) is doing better than North America (59) in terms of productivity. Regarding the multidimensional determinants of productivity, this study has found that macroeconomic variables, innovative variables, and infrastructural variables mainly determine the MPI. The broad findings of this study suggest that there is no difference in TFP among developed, developing, and least developed countries. Further, there is no significant impact of regions and alliances on TFP across countries worldwide. This strongly reiterates the reality of global productivity convergence. Although the current study tried to accommodate the maximum number of relevant variables to create a comprehensive MPI, a few variables were omitted for having an insignificant influence on the index. Theoretically, this research expands the scope of Kim et al.'s (2018) measurement of MPI by including capital as an input alongside labor and energy consumption, based on 50 components and under 11 indices (including democracy, global competitiveness, and innovation index). In practice, a large number of nations, global leaders, and regional vendors may recognize the importance of productivity competitiveness and take further steps to improve their own productivity. Future studies may overcome these limitations by including more countries. Further, an exhaustive multidimensional productivity index of all the countries in the world may be a worthy complement to this study.

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Contact information

Md Harun Or Rosid
Huazhong University of Science and Technology
School of Management
Management Science and Engineering
China
E-mail: harunaisbu@gmail.com
ORCID: 0000-0002-4179-958X

Prof. Zhao Xuefeng
Huazhong University of Science and Technology
School of Management
Management Science and Engineering
China
E-mail: zxfoliver@hust.edu.cn

Reajmin Sultana
Bangladesh University of Professionals
Faculty of Business Studies
Department of Business Administration - General
Bangladesh
E-mail: reajmin@gmail.com
ORCID: 0000-0002-4998-7948

Najmul Hasan (Corresponding Author)
Huazhong University of Science and Technology
School of Management
Management Science and Engineering
China
E-mail: nhasandsr@gmail.com
ORCID: 0000-0003-2108-6918