BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine
www.businessperspectives.org

Agung Riyardi (Indonesia), **Mohd Fahmy-Abdullah** (Malaysia),
Maulidyah Indira Hasmarini (Indonesia), **Kusdiyanto** (Indonesia)

COMBINING AGGREGATE PRODUCTION FUNCTION AND TECHNICAL EFFICIENCY: INDONESIAN CASE STUDY

Abstract

Besides frontiers and Data Enveloped Analysis approaches, a combination between the aggregate production function and technical efficiency can be performed using the Corrected Ordinary Least Square approach. Unfortunately, there are no studies in Indonesia that use this approach. This paper mainly studies how the Corrected Ordinary Least Square approach combines aggregate production function and technical efficiency. The methods are aggregate production function modeling, aggregate production function correcting, and technical efficiency measuring. The data are Gross Regional Domestic Product at a constant price, the number of workers, investment expenditure, education, and health data of Indonesian provinces from 2015 to 2020. There are three results. First, the Indonesian fixed effect panel data aggregate production function is the best model. In this model, Gross Regional Domestic Product at a constant price is influenced by the number of workers, investment expenditure, and human capital. Human capital consists of education and health level. Second, the deterministic frontier aggregate production function shifts the best-fixed effect model so that the constant becomes –15.36. Third, the Indonesian technical efficiency when no factors influence inefficiency is on average 0.9936. All the results indicate that human capital, aggregate production and technical efficiency combination, and the Corrected Ordinary Least Square approach are practical values.

Received on: 26th of July, 2022
Accepted on: 16th of September, 2022
Published on: 28th of September, 2022

Agung Riyardi, Dr., Associate Professor, Economics Department, Universitas Muhammadiyah Surakarta, Indonesia. (Corresponding author)

Mohd Fahmy-Abdullah, Senior Lecturer, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia, Malaysia.

Maulidyah Indira Hasmarini, MS, Associate Professor, Economics Department, Universitas Muhammadiyah Surakarta, Indonesia.

Kusdiyanto, MS, Associate Professor, Management Department, Universitas Muhammadiyah Surakarta, Indonesia.

Conflict of interest statement:
Author(s) reported no conflict of interest

Keywords aggregate production function, technical efficiency, corrected ordinary least square

JEL Classification C14, O40, R10

INTRODUCTION

Many studies discussed the aggregate production function and technical efficiency. They learned aggregate production function development, aggregate technical efficiency calculation, convergency, and cluster to promote economic growth and efficiency. They also learned to reduce poverty, economic disparity, environmental damage, and crime.

However, studies about Indonesian aggregate production function and technical efficiency simultaneously are limited. Among them are Muchdie (2016), Purwono et al. (2018), and Purwono and Yasin (2020), which model the Indonesian aggregate production function, calculate technical efficiency parametrically, and identify technical efficiency convergence characteristics. On the other hand, Kataoka (2018) and Mendez and Kataoka (2021) model nonparametrically and non-stochastically, calculate technical efficiency, and identify club convergence characteristics. Other studies prefer to analyze the sectoral unit levels. Yasin and Wulan Sari (2020) and Riyardi et al. (2019) analyze the manufacturing sector, Marikan et al. (2018), Purwono and Yasin (2018), and Izzeldin et al. (2021) analyze the banking sector, and Suparno et al. (2020) analyze the tourism sector.

http://dx.doi.org/10.21511/ppm.20(3).2022.38

All of the studies raise questions about the role of the Corrected Ordinary Least Square (COLS) approach to combine aggregate production function and technical efficiency and bridging between the parametric and nonparametric approaches. In that perspective, it is essential to study Indonesian aggregate production function and technical efficiency simultaneously based on the Corrected Ordinary Least Square (COLS) approach.

1. LITERATURE REVIEW

Various literatures discussed the aggregate production function, methods of combining the aggregate production function and technical efficiency, and techniques for measuring technical efficiency. An organized review is essential in order to obtain the proper framework in combining aggregate production function and technical efficiency. The beginning of this section discusses previous studies on the aggregate production function in order to establish the aggregate production function model. After that, this section discusses previous studies on an appropriate approach to combine aggregate production functions and technical efficiency. Finally, this section reviews studies on measuring technical efficiency at the aggregate level to ensure the appropriateness of the COLS approach to measure aggregate technical efficiency.

The aggregate production function is a function in that aggregate output is determined by aggregate inputs. The main factors in the aggregate production function are aggregate output, labor, investment, and human capital. Other factors such as technology, aggregate demand, monetary, international economy, population, and institutions also serve as important factors (Barro, 2013; Chirwa & Odhiambo, 2019; Hansen, 2013; Radulović, 2020; Sharipov, 2015; Taylor et al., 2019; Zhao, 2019).

Various studies examine the Indonesian aggregate production function. They are different in the observation level, model, and variables. Some studies observe Indonesian aggregate production function at the provincial level (Anwar, 2018; Kurniawan et al., 2019; Kurniawati, 2019; Kustanto, 2020; Mendez & Kataoka, 2021), whilst others analyze at the district and city levels (Ambya et al., 2019; Atmasari et al., 2020; Hendajany et al., 2017; Yusuf et al., 2020) or country and international comparison (Habibullah et al., 2017; Puspasari, 2019; Wibowo, 2019). Most of them examine the Indonesian aggregate production function based on an ordinary least square panel data regression equation. Only Puspasari (2019) examines based on a time series data equation.

There are also differences in the chosen variables. All of them operate the number of workers. However, they are different in their aggregate output, investment, and human capital variables. Some studies prefer to approach aggregate output by Gross Regional Domestic Product (GRDP) at a constant price (Mendez, 2020; Muchdie, 2016; Purwono et al., 2018) and others prefer GRDP at a constant price per capita or GRDP at a constant price per worker (Aginta et al., 2020; Mendez & Kataoka, 2021). Regarding the investment variable, they examine investment expenditure (Muchdie, 2016; Purwono et al., 2018) or the gross fixed capital formation (Kataoka, 2018; Mendez, 2020; Mendez & Kataoka, 2021). Regarding human capital, various studies approach it with education (Leasiwal, 2013; Puspasari, 2019; Raeskyesa & Lukas, 2019), while others approach it with education and health (Anwar, 2017, 2018; Kustanto, 2020; Wibowo, 2019).

All of the Indonesian aggregate production function studies above open an opportunity to configure the Indonesian aggregate production function based on the panel data regression equation. In addition, they open an opportunity to specify and signify that GRDP at a constant price is positively influenced by the number of workers, investment expenditure, and human capital. The configuration, specification, and significance are useful to establish the frontier aggregate production function, which is important to run the COLS approach.

Corrected Ordinary Least Square (COLS) is an approach to measure technical efficiency. It has three steps. The first is specifying the initial production function equation. The specification applies the ordinary least square (OLS) approach that all inputs affect significantly output. The second is forming the frontier production function equation by adding the constant of the initial production function equation with its maximum error term. The third is measuring the technical efficiency by dividing the initial production function with the frontier equations (Alarenan et al., 2019; Julien et al., 2020; Vasanthi et al., 2017).

The COLS approach differs from the Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) approaches. All of them are approaches to measuring technical efficiency. However, the COLS approach applies a least square estimation, which is a parametric approach, while the SFA is a maximum likelihood estimation, which is a parametric-stochastic approach, and the DEA is a linear programming estimate, which is a non-parametric and non-stochastic approach (Julien et al., 2020; Vasanthi et al., 2017).

The COLS approach can also calculate cost efficiency. The calculation steps are similar to the technical efficiency calculation. The initial step is specifying the cost regression equation. The second is establishing the cost frontier equation by subtracting the constant of the initial cost equation with its highest error term. The last is estimating the cost efficiency by dividing the cost regression equation by its frontier cost equation (Alarenan et al., 2019).

All of the studies above point out that COLS can be an appropriate approach to measure technical efficiency at an aggregate level. The reason is the aggregate level applies the aggregate production function, which has similar equations and estimations to the technical efficiency measurement. The aggregate production function and the technical efficiency measurement are input-output equations. Moreover, they apply the OLS estimation. In other words, the COLS can combine aggregate production function and technical efficiency.

Technical efficiency is production efficiency where all inputs produce optimal output. If a production causes all inputs to produce optimal output, then the production is efficient. The problem is when the production leaves residue and is inefficient. Technical efficiency measurement provides a solution to reduce residue and inefficiency so that the institutional capacity strengthens (Isa, 2021; Purwono et al., 2018; Riyardi et al., 2017; Scippacercola & Sepe, 2016).

Assuming an economy as a production system, technical efficiency also occurs in the economy. Aggregate inputs mobilization occurs to produce optimal aggregate output. If aggregate inputs run optimally, then the economy is technically efficient. However, if aggregate inputs do not run optimally, then the economy faces technical inefficiency problems, which also indicates economic growth, investment, employment, and human capital problems (Fuente-Mella et al., 2020; Geissmann & Zhang, 2018; Scippacercola & Sepe, 2016; Tsekeris & Papaioannou, 2018).

Several studies discuss Indonesian technical efficiency. All of them apply panel data. However, they are different in approach and result. Muchdie (2016), Purwono et al. (2018), and Purwono and Yasin (2020) prefer Stochastic Frontier Analysis (SFA), while Kataoka (2018) and Mendez and Kataoka (2021) prefer Data Envelopment Analysis approach. Muchdie (2016) finds that technical efficiency during the Indonesian new order is higher than during the reformation era. Purwono et al. (2018) find that the Indonesian infrastructure supports technical efficiency convergence. Purwono and Yasin (2020) analyze that Indonesian technical efficiency support total factor productivity. Kataoka (2018) and Mendez and Kataoka (2021) also find that technical efficiency is convergence.

All Indonesian technical efficiency studies open a challenging opportunity to measure Indonesian aggregate efficiency based on the COLS approach. It will provide interesting lessons ranging from the COLS development, approach comparison, and future study to signify factors that affect aggregate inefficiency based on the COLS approach.

Previous studies on the aggregate production function, COLS approach, and technical efficiency measurement show that the Indonesian aggregate production function and technical efficiency combination on the COLS approach is a specific topic. It starts from the Indonesian aggregate production function model and tests the hypothesis that GRDP at a constant price is influenced positively by the number of workers, investment expendi-

http://dx.doi.org/10.21511/ppm.20(3).2022.38

ture, and human capital. After that, it applies the COLS approach by correcting to the frontier the Indonesian aggregate production function model and measuring the Indonesian technical efficiency by comparison between the tested Indonesian aggregate production and frontier.

Therefore, this paper aims to model the Indonesian aggregate production function, correct and shift the aggregate production function to its frontier, and estimate Indonesia's level of technical efficiency.

2. METHODS

This study applied three methods. The first is the Indonesian aggregate production modeling. The second is the COLS approach. The third is the technical efficiency measurement.

The Indonesian aggregate production modeling is panel data modeling. Data in this study is the annual data of 34 provinces in Indonesia from 2015 to 2020. The data consists of provincial GRDP at a constant price, the number of over 15 years old labor force, investment expenditure, higher education gross participation, and life expectancy rates data. GRDP at a constant price is an approach to aggregate output, the number of over 15 years old labor is an approach to the number of workers, investment expenditure is an approach to the amount of investment, the higher education gross participation is an approach to education human capital, and life expectancy is an approach to health human capital.

Modeling consists of model selection and significance testing. Selection is between common, fixed, and random effect models based on Lagrange Multiplier, Chow, and Hausman tests. Significance testing examines totally and partially the relationship between the Indonesian provincial GRDP at a constant price to the number of workers, investment expenditure, education, and health.

The panel data regression equation general form and its specification are:

$$LnY_{i,t} = \beta_{0_{i,t}} + \beta_2 LnX_{1_{i,t}} + \beta_3 LnX_{2_{i,t}} + \\ + \beta_4 LnX_{3_{i,t}} + \beta_5 LnX_{4_{i,t}} + \varepsilon_{i,t}, \tag{1}$$

$$LnGRDP_{i,t} = \beta_{0_{i,t}} + \beta_1 LnL_{i,t} + \beta_2 LnK_{i,t} + \\ + \beta_3 E_{i,t} + \beta_4 LnH_{i,t} + \varepsilon_{i,t}, \tag{2}$$

where *GRDP* is the gross regional domestic product at a constant price, *L* is the number of workers, *K* is investment expenditure, *E* is education, *H* is health, *i* is cross-section data, *t* is time-series data, β_0 is an intercept, 1-4 is the coefficient of $X_{1\text{-}4}$, Ln is the natural logarithm, ε is the regression equation residual.

The COLS approach shifts the aggregate production function to its frontier. There are three steps. First, calculating the maximum error term of the Indonesian aggregate production function as in Equation 2. Second, adding the constant of Equation 2, $\beta_{0I,t}$, by the maximum error term so that the Indonesian aggregate production becomes the frontier Indonesian aggregate production function. Equation 3 shows the frontier aggregate production function. The *f* symbol in Equation 3 means that the equation is the frontier equation. Third, calculating the GRDP at a constant price based on the initial and frontier aggregate production function.

$$LnGRDP_{i,t}^{f} = (\beta_{0_{i,t}} + \varepsilon_{i,t_{\max}}) + \beta_1 LnL_{i,t} + \\ + \beta_2 LnK_{i,t} + \beta_3 E_{i,t} + \beta_4 LnH_{i,t}. \tag{3}$$

The technical efficiency measurement is by the division between the GRDP at a constant price obtained from the initial aggregate production function to the GRDP at a constant price obtained from the frontier equation. The long formula for calculating technical efficiency (ET) is:

$$ET_{i,t} = \frac{LnGRDP_{i,t}}{LnGRDP_{i,t}^{f}} = \\ = \left(\beta_{0_{i,t}} + \beta_1 LnL_{1_{i,t}} + \beta_2 LnK_{2_{i,t}} + \beta_3 E_{3_{i,t}} + \\ + \beta_4 LnH_{4_{i,t}} + \varepsilon_{i,t}\right) / \left(\beta_{0_{i,t}} + \varepsilon_{i,t_{\max}} + \beta_1 LnL_{1_{i,t}} + \\ + \beta_2 LnK_{2_{i,t}} + \beta_3 E_{3_{i,t}} + \beta_4 LnH_{4_{i,t}}\right), \tag{4}$$

where the upper equation is the initial aggregate production function, whilst the lower is the frontier aggregate production function.

Technical efficiency ranges from 0 to 1. Zero means extremely inefficient. Various factors cause inefficient production. One means very efficient where there are no factors that cause inefficient conditions.

3. RESULTS

This section presents all of the results. The first is the Indonesian aggregate production function testing and modeling. The second is the COLS approach application. It consists of correcting and shifting the Indonesian aggregate production function model and measuring Indonesian technical efficiency.

The Indonesian aggregate production function model is the fixed effect model (FEM) regression equation. Table 1 shows that all models provide significant explanatory variables. However, the Lagrange Multiplier test decides that the random effect model (REM) is more appropriate than the common effect model (CEM), the Chow test decides that FEM is more appropriate than CEM, and the Hausman test decides that FEM is more appropriate than REM. Therefore, the best model is the fixed effect aggregate production function (Note: The process and results of the model selection are not shown in this paper).

Table 1. Indonesian aggregate production function model

Source: Statistical estimation.

Variable		CEM	FEM	REM
$C_{i,t}$	Coefficient	–8.5425	–15.4799	–14.3690
	Standard Error	2.2842	4.0447	3.1586
	t-statistic	–3.7398*	–3.8272*	–4.5492*
$LNL_{i,t}$	Coefficient	0.7243	0.1111	0.1922
	Standard Error	0.0310	0.0267	0.0250
	t-value	23.3954*	4.1622*	7.6797*
$LNK_{i,t}$	Coefficient	0.2362	0.4092	0.6641
	Standard Error	0.0320	0.0916	0.0448
	t-value	7.390*	4.4656*	14.8243*
$E_{i,t}$	Coefficient	–0.0083	0.0099	0.0048
	Standard Error	0.0017	0.0016	0.0013
	t-value	–4.8825*	6.1638*	3.6007*
$LNH_{i,t}$	Coefficient	2.6945	6.1468	4.7149
	Standard Error	0.5805	1.1375	0.8156
	t-value	4.6418*	5.4037*	5.7810*

Note: Dependent variable: LNGRDP, * = Significant at α = 5%.

The Indonesian fixed effect panel data aggregate production function has three important features. The first is all inputs influence significantly the aggregate output. The second is the significance of the constant term. The third is human capital consists of education and health variables.

Equation 5 shows the frontier Indonesian aggregate production function. The origin of this equation is the Indonesian fixed effect aggregate production function model. Equation 5 has three characteristics. The first is this equation is a frontier equation. This is shown by the *f* symbol on the upper left side of Equation 5. The second is the constant coefficient. It is a sum of the initial aggregate production function constant and its maximum error. It is –15.36= –15.48 + 0.12. The third is the equation is without an error term. It means that the equation is non-stochastic or deterministic.

$$LnGRDP_{i,t}^{f} = -15.36 + 0.11 LnL_{i,t} + \\ +0.41 LnK_{i,t} + 0.009 E_{i,t} + 6.16 LnH_{i,t}. \quad (5)$$

The Indonesian technical efficiency consists of provincial efficiency. The average value is 0.9936. The lowest technical efficiency is Bengkulu province technical efficiency, 0.9928, and the highest technical efficiency is DKI Jakarta, 0.9943. All provincial efficiencies are close to one and show that the Indonesian economy is technically efficient (see Table 2).

Table 2. Average value of Indonesian technical efficiency from 2015 to 2020

Source: Statistical estimation.

Provinces	Technical efficiency	Provinces	Technical efficiency
Aceh	0.993516	West Nusa Tenggara	0.993416
North Sumatera	0.993964	East Nusa Tenggara	0.993279
West Sumatera	0.993601	West Kalimantan	0.993524
Riau	0.993950	Central Kalimantan	0.993408
Jambi	0.993556	South Kalimantan	0.993516
South Sumatera	0.993796	East Kalimantan	0.993941
Bengkulu	0.993128	North Kalimantan	0.993229
Lampung	0.993716	North Sulawesi	0.993366

http://dx.doi.org/10.21511/ppm.20(3).2022.38

Table 2 (cont.). Average value of Indonesian technical efficiency from 2015 to 2020

Provinces	Technical efficiency	Provinces	Technical efficiency
Bangka Belitung Islands	0.993191	Central Sulawesi	0.993466
Riau Islands	0.993623	South Sulawesi	0.993804
DKI Jakarta	0.994306	Southeast Sulawesi	0.993383
West Jawa	0.994253	Gorontalo	0.992923
Central Jawa	0.994140	West Sulawesi	0.992983
DI Yogyakarta	0.993422	Maluku	0.992964
East Jawa	0.994280	North Maluku	0.992895
Banten	0.993911	West Papua	0.993244
Bali	0.993573	Papua	0.993565

4. DISCUSSION

The first result is the Indonesian fixed effect panel data aggregate production function. This aggregate production function has three characteristics. The output is GRDP at constant price, inputs are number of workers, investment expenditure, and education and health as a human capital, and all inputs affect positively the output.

The Indonesian fixed effect panel data aggregate production function is the best model. It successfully passed model selection, data normality, and variable significance statistical tests. In addition, all dependent variables have a positive sign.

This result confirms previous studies. Observations at the provincial level confirm many studies of Indonesian aggregate production function at the provincial level such as Anwar (2018), Kurniawan et al. (2019), Kustanto (2020), and Mendez and Kataoka (2021). The significance of variables explains studies of GRDP at a constant price as aggregate output as Mendez (2020), Muchdie (2016), and Purwono et al. (2018), investment expenditure as Muchdie (2016), and Purwono et al. (2018), and education and health as human capital as Anwar (2017), Anwar (2018), Wibowo (2019), and Kustanto (2020).

This aggregate production function model serves as a base for the COLS approach. Correcting and shifting develops it as a frontier aggregate production function. Comparing it to the frontier provides technical efficiency measuring.

The second result is the frontier Indonesian aggregate production function. Aggregate production in this stage successfully mobilizes all inputs to produce optimal output without any residue. It represents the highest technical efficiency.

This finding signifies three things. Firstly, it is an important COLS approach development besides previous sectoral and unit developments as studied by Vasanthi et al. (2017), Alarenan et al. (2019), and Julien et al. (2020). Secondly, the COLS forms the frontier by correcting and shifting the initial function. It is different from SFA and DEA approaches. The COLS corrects the constant parameter deterministically, SFA stochastically, and DEA based on linear programming. Thirdly, the COLS approach is a middle way to the SFA and DEA approaches, which has been studied by Purwono et al. (2018), Purwono and Yasin (2020), Kataoka (2018), and Mendez and Kataoka (2021). The COLS approach establishes the stochastic initial aggregate production function equation, which is similar to the SFA initial approach, and establishes a deterministic frontier equation, which is comparable to the DEA equation.

The Indonesian aggregate production function serves as a benchmark for technical efficiency measurement. It divides the initial Indonesian aggregate production function. The aggregate production is efficient if the initial equation is similar to the frontier equation.

The third result is the Indonesian technical efficiency level. The average technical efficiency is 0.9936, which is close to 1 as the highest level of technical efficiency. This perfect efficiency indicates two important things. Firstly, it shows that factors causing inefficiency are not involved in the aggregate production function estimation. An example of a factor causing inefficiency is dispersed aggregate production, which is the opposite of cluster or club production as studied by Muchdie (2016), Purwono et al. (2018), and Purwono and Yasin (2020). Another example is divergence aggregate production, which is different from convergence production as studied by Kataoka (2018) and Mendez and Kataoka (2021). Secondly, it indicates the COLS approach appropriateness. When the various factors that affect the inefficiency are not included, the initial and frontier equations are relatively the same. As a result, the efficiency level becomes very close to one and indicates that the aggregate production runs efficiently.

It means that future studies have an opportunity to develop aggregate production function and technical efficiency combination based on the COLS approach by incorporating factors such as cluster and convergency. Another prospect is to examine negative externality factors such as poverty, disparity, environmental damage, and crime. All of them enrich the COLS development and are vital for macroeconomic decision making.

CONCLUSION

The central concept of this paper is combining aggregate production function and technical efficiency based on the COLS approach. Indonesian case shows that setting the aggregate production function model and shifting the model to its frontier deterministically leads to the highest level of technical efficiency. It means that the COLS approach works properly to integrate the aggregate production function and technical efficiency.

There are three novelties from this paper. The first is the role of human capital, especially the health factor to form the Indonesian aggregate production function. The second is the combination of the aggregate production function and the technical efficiency. The third is the role of the COLS approach.

The results and novelties provide two implications. The first is the practical use implication. The economy should pay attention to the aggregate production function and technical efficiency. This attention includes attention to health level and negative externalities that affect technical efficiency such as divergency, poverty, disparity, environmental damage, and crime. The second is the implication of future research. Future studies have a big opportunity to apply the COLS approach to test human capital that affects aggregate output and negative externalities that decrease aggregate technical efficiency. These studies will provide a valuable academic base for economic policy.

AUTHOR CONTRIBUTIONS

Conceptualization: Agung Riyardi.
Formal analysis: Agung Riyardi, Mohd Fahmy Abdullah, Kusdiyanto.
Funding acquisition: Agung Riyardi.
Investigation: Agung Riyardi, Kusdiyanto.
Methodology: Agung Riyardi, Mohd Fahmy Abdullah.
Project administration: Maulidyah Indira Hasmarini, Kusdiyanto.
Resources: Maulidyah Indira Hasmarini, Kusdiyanto.
Software: Maulidyah Indira Hasmarini.
Supervision: Agung Riyardi.
Validation: Mohd Fahmy Abdullah, Maulidyah Indira Hasmarini.
Visualization: Mohd Fahmy Abdullah.
Writing – original draft: Agung Riyardi, Maulidyah Indira Hasmarini.
Writing – review & editing: Agung Riyardi, Mohd Fahmy Abdullah.

REFERENCES

1. Aginta, H., Gunawan, A. B., & Mendez, C. (2020). *Regional Income Disparities and Convergence Clubs in Indonesia: New District-Level Evidence 2000–2017* (MPRA Paper). https://doi.org/10.21203/rs.3.rs-29036/v1
2. Alarenan, S., Gasim, A. A., Hunt, L. C., & Muhsen, A. R. (2019). Measuring underlying energy efficiency in the GCC countries using a newly constructed dataset. *Energy Transitions, 3*(1-2), 31-44. https://doi.org/10.1007/s41825-019-00012-y
3. Ambya, Nairobi, Suparta, I. W., Desfiandi, A., & Said, J. (2019).

http://dx.doi.org/10.21511/ppm.20(3).2022.38

The disparity and the convergence of the economic growth: The study of the new autonomous regions in Sumatera, Indonesia. *Humanities and Social Sciences Reviews, 7*(6), 673-679. https://doi.org/10.18510/hssr.2019.76101

4. Anwar, A. (2017). Peran Modal Manusia Terhadap Pertumbuhan Ekonomi Regional Di Jawa. *Jurnal Economia, 13*(1), 79-94. https://doi.org/10.21831/economia.v13i1.13323
5. Anwar, A. (2018). Pendidikan, Kesehatan Dan Pertumbuhan Ekonomi Regional Di Indonesia: Pendekatan Model Panel Dinamis. *Jurnal Ekonomi & Studi Pembangunan, 19*(1), 50-60. https://doi.org/10.18196/jesp.19.1.2727
6. Atmasari, N. M., Priyono, T. H., & Viphindrartin, S. (2020). Konvergensi Pertumbuhan Ekonomi Kota dan Kabupaten Klaster Metropolitan Jawa Timur. *E-Journal Ekonomi Bisnis Dan Akuntansi, 7*(2), 91-97. https://doi.org/10.19184/ejeba.v7i2.17867
7. Barro, R. J. (2013). Health and economic growth. *Annals of Economics and Finance, 14*(2), 305-342. Retrieved from http://down.aefweb.net/AefArticles/aef140202Barro.pdf
8. Chirwa, T. G., & Odhiambo, N. M. (2019). An empirical test of exogenous growth models: Evidence from three Southern African countries. *Economic Annals, 64*(220), 7-38. https://doi.org/10.2298/EKA1920007C
9. Fuente-Mella, H., Vallina-Hernandez, A. M., & Fuentes-Solís, R. (2020). Stochastic analysis of the economic growth of OECD countries. *Economic Research-Ekonomska Istrazivanja, 33*(1), 2189-2202. https://doi.org/10.1080/1331677X.2019.1685397
10. Geissmann, T., & Zhang, L. (2018). Knowledge economy and industry performance in China: a provincial level analysis. *Journal of Chinese Economic and Business Studies, 16*(4), 393-415. https://doi.org/10.1080/14765284.2018.1507980
11. Habibullah, M. S., Chong, C. Y., & Din, B. H. (2017). Developing and developed ASEAN-10 economies: Converge or diverge? *International Journal of Economics and Management, 11*(3 Special Issue), 623-640. Retrieved from http://psasir.upm.edu.my/id/eprint/61440/
12. Hansen, C. W. (2013). Health and development: A neoclassical perspective. *Journal of Human Capital, 7*(3). https://doi.org/10.1086/674076
13. Hendajany, N., Saepudin, D., & Suaesih, A. (2017). Beta Convergence and Sigma Convergence: Evidence from Indonesian District-Level Data. *Jurnal Ekonomi Kuantitatif Terapan, 10*(1), 19-25. https://doi.org/10.24843/jekt.2017.v10.i01.p03
14. Isa, M. (2021). Strengthening Institutional Capacity of Guitar Cluster: Implementation of DEA and MACTOR. *Ekuilibrium, 16*(2), 107-116. https://doi.org/10.24269/ekuilibrium.v16i2.3488
15. Izzeldin, M., Johnes, J., Ongena, S., Pappas, V., & Tsionas, M. (2021). Efficiency convergence in Islamic and conventional banks. *Journal of International Financial Markets, Institutions and Money, 70,* 101279. https://doi.org/10.1016/j.intfin.2020.101279
16. Julien, S. A., Cowie, J., & Monios, J. (2020). Efficiency, productivity and returns to scale in ports: a comparison of data envelopment analysis and econometric estimation with application to Caribbean Small Island Developing States. *Maritime Economics and Logistics, 22*(2), 239-264. https://doi.org/10.1057/s41278-018-0115-y
17. Kataoka, M. (2018). Inequality convergence in inefficiency and interprovincial income inequality in Indonesia for 1990–2010. *Asia-Pacific Journal of Regional Science, 2*(2), 297-313. https://doi.org/10.1007/s41685-017-0051-3
18. Kurniawan, H., de Groot, H. L. F., & Mulder, P. (2019). Are poor provinces catching-up the rich provinces in Indonesia? *Regional Science Policy and Practice, 11,* 89-108. https://doi.org/10.1111/rsp3.12160
19. Kurniawati, S. (2019). Regional Income and its Convergence in Indonesia. *International Journal of Economics and Financial Issues, 9*(6), 77-83. https://doi.org/10.32479/ijefi.8689
20. Kustanto, A. (2020). Pertumbuhan Ekonomi Regional Di Indonesia: Peran Infrastruktur, Modal Manusia Dan Keterbukaan Perdagangan. *Buletin Studi Ekonomi, 25*(1), 80-98. https://doi.org/10.24843/bse.2020.v25.i01.p05
21. Leasiwal, T. C. (2013). The Analysis of Indonesia Economic Growth: A Study in Six Big Islands in Indonesia. *Journal of Economics, Business, and Accountancy Ventura, 16*(1), 1-12. Retrieved from https://journal.perbanas.ac.id/index.php/jebav/article/view/121
22. Marikan, D. A. A., Rahim, R. A., Habibullah, M. S., & Rahman, M. M. (2018). The club convergence of efficiency in ASEAN banking sector. *International Journal of Economics and Management, 12*(1), 1-31. Retrieved from https://ir.unimas.my/id/eprint/25342/1/The%20club%20convergence%20of%20efficiency%20in%20ASEAN%20banking%20sector%20(abstract).pdf
23. Mendez, C. (2020). Regional efficiency convergence and efficiency clusters: Evidence from the provinces of Indonesia 1990–2010. *Asia-Pacific Journal of Regional Science, 4*(2), 391-411. https://doi.org/10.1007/s41685-020-00144-w
24. Mendez, C., & Kataoka, M. (2021). Disparities in regional productivity, capital accumulation, and efficiency across Indonesia: A club convergence approach. *Review of Development Economics, 25*(2), 790-809. https://doi.org/10.1111/rode.12726
25. Muchdie, M. (2016). Technical Efficiency and Return to Scale in The Indonesia Economy During the New Order and The Reformation Governments.

Jurnal Ekonomi Pembangunan: Kajian Masalah Ekonomi Dan Pembangunan, 17(2), 136. https://doi.org/10.23917/jep.v17i2.2430

26. Purwono, R., & Yasin, M. Z. (2018). The Convergence Test of Indonesia Banking Inefficiency: Do Macroeconomic Indicators Matter? *Buletin Ekonomi Moneter Dan Perbankan, 21*(1), 123-137. https://doi.org/10.21098/bemp.v21i1.946

27. Purwono, R., & Yasin, M. Z. (2020). Does Efficiency Convergence of Economy Promote Total Factor Productivity? A Case of Indonesia. *Journal of Economic Development, 45*(4), 69-91. https://doi.org/10.35866/caujed.2020.45.4.004

28. Purwono, R., Mubin, M. K., & Yasin, M. Z. (2018). Do infrastructures influence the efficiency convergence of the Indonesian economy? *Seoul Journal of Economics, 31*(3), 333-353. https://doi.org/10.22904/sje.2018.31.3.004

29. Puspasari, S. (2019). Pengaruh Partisipasi Angkatan Kerja Terdidik Terhadap Pertumbuhan Ekonomi di Indonesia: Perspektif Modal Manusia. *Jurnal Ilmu Administrasi: Media Pengembangan Ilmu Dan Praktek Administrasi, 16*(2), 194-209. https://doi.org/10.31113/jia.v16i2.500

30. Radulović, M. (2020). The Impact of Institutional Quality on Economic Growth: A Comparative analysis of the EU and Non-EU countries of Southeast Europe. *Economic Annals, 65*(225), 163-181. https://doi.org/10.2298/EKA2025163R

31. Raeskyesa, D. G. S., & Lukas, E. N. (2019). Does Digitalization Increase Economic Growth? Evidence from ASEAN8 Countries. *Jurnal Ekonomi Indonesia, 8*(2), 267-278. https://doi.org/10.52813/jei.v8i2.33

32. Riyardi, A., Cahyani, A. L., & Prasetya, S. P. (2017). Analisis Inefisiensi Teknis Pertanian Padi Organik dan Anorganik di Kecamatan Kebakkramat Kabupaten Karanganyar Berdasarkan Fungsi Produksi Frontier Stokastik. *6th University Research Colloquium 2017: Seri Humaniora, Sosial, Dan Agama* (pp. 531-540). Retrieved from https://journal.unimma.ac.id/index.php/urecol/article/view/1233

33. Riyardi, A., Triyono, & Triyono. (2019). Cost inefficiency of large and medium industries in Indonesia. In *Business Innovation and Development in Emerging Economies* (pp. 507-518). CRC Press. https://doi.org/10.1201/9780429433382-48

34. Scippacercola, S., & Sepe, E. (2016). Critical comparison of the main methods for the technical efficiency. *Electronic Journal of Applied Statistical Analysis, 9*(4), 760-780. https://doi.org/10.1285/i20705948v9n4p760

35. Sharipov, I. (2015). Contemporary economic growth models and theories: A literature review. *CES Working Papers, VII*(3), 759-773. Retrieved from https://ceswp.uaic.ro/articles/CESWP2015_VII3_SHA.pdf

36. Suparno, Ujianto, & Sumiati. (2020). Analysis of Competitiveness of the Tourism Sector East Java Province (A Technical Efficiency & Convergence Approach). *Archives of Business Research, 8*(6), 294-304. https://doi.org/10.14738/abr.86.8585

37. Taylor, L., Foley, D. K., & Rezai, A. (2019). Demand drives growth all the way: Goodwin, Kaldor, Pasinetti and the steady state. *Cambridge Journal of Economics, 43*(5), 1-20. https://doi.org/10.1093/cje/bey045

38. Tsekeris, T., & Papaioannou, S. (2018). Regional determinants of technical efficiency: evidence from the Greek economy. *Regional Studies, 52*(10), 1398-1409. https://doi.org/10.1080/00343404.2017.1390312

39. Vasanthi, R., Sivasankari, B., & Gitanjali, J. (2017). A stochastic frontier and corrected Ordinary Least Square models of determining technical efficiency of canal irrigated paddy farms in Tamil Nadu. *Journal of Applied and Natural Science, 9*(2), 658-662. https://doi.org/10.31018/jans.v9i2.1253

40. Wibowo, M. G. (2019). Human Capital Relation with Welfare in Indonesia and Asean Countries. *Economics Development Analysis Journal, 8*(1), 81-93. https://doi.org/10.15294/edaj.v8i1.28730

41. Yasin, M. Z., & Wulan Sari, D. (2020). Convergence of Efficiency in Manufacturing Industry in Indonesia: Stochastic Frontier Analysis Approach. *Palarch's Journal of Archaeology of Egypt/Egyptology, 17*(3), 2115-2133. Retrieved from https://archives.palarch.nl/index.php/jae/article/view/988

42. Yusuf, M. G., Susilo, J. H., & Tsani, L. I. (2020). Application of the Generalized Method of Moment Arellano-Bond on Economic Growth in Central Java Province in 2011–2018. *International Journal of Innovative Science and Research Technology, 5*(8), 1029-1037. https://doi.org/10.38124/ijisrt20aug572

43. Zhao, R. (2019). Technology and economic growth: From Robert Solow to Paul Romer. *Human Behavior and Emerging Technologies, 1*(1), 62-5. https://doi.org/10.1002/hbe2.116

http://dx.doi.org/10.21511/ppm.20(3).2022.38