Effect of COVID-19 on energy consumption and carbon dioxide emissions in Indonesia

by Arief Anshory Yusuf

Sustainable Production and Consumption 28 (2021) 391–404

Contents lists available at ScienceDirect

Sustainable Production and Consumption

journal homepage: www.elsevier.com/locate/spc

Effect of COVID-19 on energy consumption and carbon dioxide emissions in Indonesia

Djoni Hartono[a,b,#,*], Arief Anshory Yusuf[c], Sasmita Hastri Hastuti[b], Novani Karina Saputri[b], Noor Syaifudin[d]

[a] Faculty of Economics and Business, Universitas Indonesia, Depok, Indonesia
[b] Research Cluster on Energy Modeling and Regional Economic Analysis, Universitas Indonesia, Depok, Indonesia
[c] Faculty of Economics and Business, Universitas Padjadjaran, Bandung, Indonesia
[d] Fiscal Policy Agency, Ministry of Finance, Republic of Indonesia, Jakarta, Indonesia

ARTICLE INFO

Article history:
Received 14 January 2021
Revised 1 June 2021
Accepted 7 June 2021
Available online 11 June 2021

Editor: Dr. Paula De Camargo Fiorini

Keywords:
Computable General Equilibrium Model
Covid-19
Energy Consumption
CO_2 Emissions

ABSTRACT

Despite the pandemic's negative effect on the economy, it can help reduce emissions from energy consumption activities in line with the Paris Agreement, especially for high-emitter countries such as Indonesia. However, the policy response to COVID-19 may rebound the emissions to their pre-pandemic levels. To design an efficient policy that considers both economic and environmental variables, this study uses a computable general equilibrium model that assesses how COVID-19 and its stimulus policy will affect the macroeconomic indicator, energy consumption, and emissions at the national and regional levels. The results show that macroeconomic indicators generally performed worse with the current stimulus policy in the short run than in the long run. Refined petroleum energy consumption took the highest hit, followed by coal-based energy consumption and overall electricity demand. The pattern in emissions reduction is similar to the pattern of gross domestic product declination as well. The Sulawesi region particularly experienced the largest decrease in refined petroleum energy consumption. In contrast, the Java-Bali and Sumatra regions experienced the most coal-based energy consumption reduction and the largest emissions reduction. Should COVID-19 provide the impetus to develop more environmentally sound economic development, we would need better policy to address the recovery. Returning to pre-pandemic development will not lead to long-term environmental gain. This study offers policy recommendations for economic recovery and environmental improvement. The government should promote low-carbon technology, clean energy transition, more energy efficiency, and sustainable development to avoid the rebound effect of energy consumption and carbon emission. Coordination between central and local governments is also needed to formulate a fiscal policy inclined toward low-carbon pathways.

1. Introduction

Since December 2019, the severe acute respiratory syndrome coronavirus 2 has led to millions of COVID-19 infections around the world and an increasing death toll. Countries continue to close borders and impose stringent transmission control policies to limit mobility and congregation to suppress the transmission of the virus (Nicola et al., 2020). The resulting change in behavior, the uncertainty of the progression of the pandemic, and the transmission control policies together have had implications beyond the immediate effect on health. The direct effects of COVID-19 on the economy and human well-being have been extensively discussed (Asian Development Bank, 2020; McKibbin and Fernando, 2020; Oskoui, 2020). COVID-19 has also had environmental effects, such as on energy consumption and emissions, although few studies have captured these changes.

The restrictions on mobility and economic activity are a challenging combination of a supply and demand shock, mainly because of breaks in the supply chain and contraction in demand (Association of South East Asian Nations, 2020; Asian Development Bank, 2020; Oskoui, 2020). The year 2020 witnessed the greatest decline in global economic growth since the Great Depression of the 1930s (IMF, 2020). Indonesia saw its greatest decline since the 1997 Asian Financial Crisis. Its gross domestic product (GDP) is estimated to fall by around 1.3% to 3.21%, based on different

* Corresponding author at: Department of Economics, Faculty of Economics and Business, Universitas Indonesia.
E-mail address: djoni.hartono@ui.ac.id (D. Hartono).
Department of Economics Building, Widjojo Nitisastro Campus., Prof. Dr. Sumitro Djojohadikusumo, Str. UI Depok Campus 16424, Depok, Indonesia.

https://doi.org/10.1016/j.spc.2021.06.003
2352-5509/

Nomenclature

X	Output
D	Local intermediate input
C	Imported intermediate input
K	Capital
L	Labor
N	Land
i	Index for sector
c	Index for commodity
j	Index for labor type
r	Index for region
t	Index for year
$\alpha, \beta, \gamma, \tau$	Constant elasticity of substitution (CES) share parameters
ρ	CES substitution parameter
a^X	All-input augmenting technical change parameter
E	CO_2 emissions
δ	Constant to transform carbon to CO_2 emissions
ϖ	Oxidation factor
CC	Carbon content
Φ	Factor to convert BOE to Gigajoules
X^E	Quantity of energy consumption
f	Index for energy type
u	Index for energy user

assumptions (Anderson and McKibbin, 2000; Maliszewska et al., 2020). This projection especially includes the large-scale social restrictions policy implemented during April to early June 2020 as well as weakening global demand for exports, including commodities (mostly coal and palm oil), as reflected in the significant decline in commodity prices (Olivia et al., 2020). These projections gage the effect of the pandemic on the economy only.

Large-scale transmission control policies, a dramatic fall in travel, and low economic activity may change energy consumption patterns and emissions. The data of the Directorate General of Electricity, Ministry of Energy and Mineral Resources of Indonesia show that the consumption of electricity and liquid petroleum gas in Indonesia is relatively higher than average consumption level in the same period in the previous years (2016–2019), while fuel consumption decreased. Since anthropogenic activity was the primary source of carbon dioxide (CO_2) emissions (International Energy Agency (IEA), 2017; Coordinating Ministry for Economic Affairs & United Nations Development Programme, 2018), the change in energy consumption pattern may also correlate with the level of emissions. However, no assessment of emissions in Indonesia for 2020 has been done yet. At the global level, climate experts estimate that greenhouse gas (GHG) emissions may drop to proportions not seen since World War II (Global Carbon Project, 2020).

To combat climate change, Indonesia has pledged a target emissions reduction of 29% below business-as-usual unconditionally, or 41% conditionally, by 2030 as per the Paris Agreement (Ministry of Energy and Mineral Resources, 2016). However, the progress toward this target has remained “highly insufficient.” Since energy consumption is one of the main sources of emissions, the probability that emissions may have plummeted because of the change in energy consumption may be an essential issue, as reducing emissions in Indonesia is of global interest (Yusuf and Resosudarmo, 2008). Knowing the changes in energy consumption in different sectors and regions may also help control the energy demand, since Indonesia is a large and heterogeneous country. A more regional-specific assessment is needed to develop policy.

At the same time, whether the environment effect is temporary or permanent as the government prepares to stimulate the economy is another concern. Although COVID-19 has harmed the economy, gaging the pandemic’s environmental effect may allow us to see if COVID-19 offers an opportunity to attain Goal 7 and 13 of the Sustainable Development Goals, namely, transitioning energy consumption and combating climate change.

Under these circumstances, this study examines the economic outcomes and the environmental consequences of the pandemic. The effects may depend on the duration of transmission control policy, the severity of the transmission control policy, and the endowment features of each region. An economy-wide effect like this should typically be approached by an economy-wide model such as the computable general equilibrium (CGE) model. Arrow (2005) states that “[*i*]n all cases where the repercussions of proposed policies are widespread, there is no real alternative to CGE.” Indeed, some earlier attempts to estimate the effect of COVID-19 on the economy employ general equilibrium models. McKibbin and Fernando (2020), for instance, apply the G-cubed dynamic global economic model. This study applied several alternatives, but not mutually exclusive characterizations, of the economic shock caused by the pandemic. Maliszewska et al. (2020) use the World Bank’s ENVISAGE general equilibrium model to make similar global projections on the effect of COVID-19. The Asian Development Bank (2020) uses a general equilibrium model under the Global Trade Analysis Project to gage the effect of COVID-19 on Asian economies. To the best of our knowledge, no study uses a general equilibrium analysis of the effect of COVID-19 focusing on the environmental effect, particularly its effect on CO_2 emissions. Our analysis address this limitation in the literature.

Recent studies show that Indonesia’s GDP may decrease by up to 3.21% because of the restrictions on mobility and activities during the pandemic (Anderson & McKibbin, 2020; Asian Development Bank, 2020; Maliszewska et al., 2020). Compared to Indonesia’s GDP data in the fourth quarter of 2019, the economy contracted by 2.4% at the end of the first quarter of 2020. This condition is heavily driven by decreasing consumption, which accounts for more than half of Indonesia’s GDP. Suryahadi (2020) also found that the poverty rate was expected to increase by up to 12.37% because of the pandemic. Although studies on Indonesia do exist, they are conducted on a nationwide scale. However, Indonesia comprises many regions with heterogenous characteristics. The effect of COVID-19 on different regions in the country may thus be heterogenous as well. This makes a national-level analysis inadequate to assess the effect of the pandemic on the country’s economy and environment. We thus present a region-specific analysis along with a national analysis.

Using the inter-regional CGE model, we assess how COVID-19 and its stimulus policy affect the economy, energy consumption, and emissions. In the model, several mechanisms are used to show how the COVID-19 pandemic alters the behavior of the economy. These mechanisms show a disruption in the global production chain to international trade as well as declines in international tourism activities, personal trips, and economic activities. These four mechanisms are reflected in the proposed model using datasets from the Asian Development Bank analysis on international trade, United Nations International Trade Statistics, and Google Mobility among others.

We present two alternative scenarios based on the model, namely, pessimistic and optimistic. In the pessimistic scenario, the economy will not recover, while the opposite is true for the optimistic scenario. Both scenarios assume a fiscal stimulus policy from the Indonesian government. Based on the simulation results, we present insights on how macroeconomic and environmental indicators as well as variables of energy consumption perform under the stress of the COVID-19 pandemic.

This study contributes to the literature in three ways. First, to the best of our knowledge, this is the first study to explore the

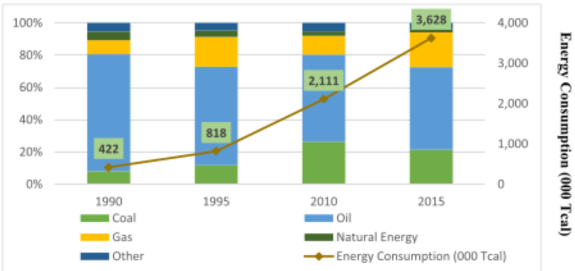

Fig. 1. Primary Energy Mix and Total Energy Consumption
Source: Indonesia Central Agency on Statistics and Author's Calculation (2020).

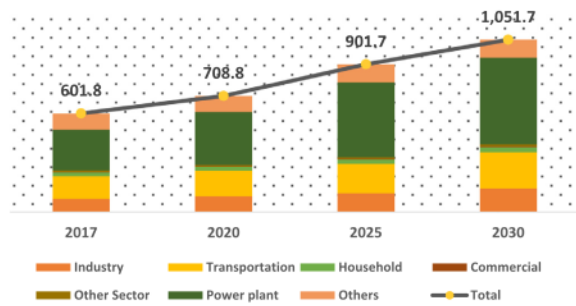

Fig. 2. Energy's GHG Emissions Projection by Sector
Source: Agency for the Assessment and Application of Technology, 2019.

effect of COVID-19 on environmental aspects in Indonesia. Second, we evaluate the effects COVID-19 both nationally and regionally, as the latter is seldom explored. Third, the emission levels can rebound from stimulus policies during the pandemic. Thus, the thorough calculation of CO_2 emissions changes not only due to COVID-19, but the stimulus policy may also provide vital information to design a specific policy to attain Indonesia's national determined contribution.

The remaining paper is structured as follows: Section 2 presents a review of the literature on energy consumption and emissions in Indonesia and inter-regional CGE. Section 3 describes the methodology, Section 4 explores the result, and Section 5 concludes.

2. Literature review

2.1. Indonesia energy consumption and emissions

Indonesia's primary energy consists of refined petroleum, natural gas, coal, and renewable energy. Fig. 1 shows the historical change of the primary energy mix in Indonesia. In 1990, refined petroleum energy was the primary energy source, which changed to coal and gas. In 2018, production energy consumption accounted for 1533.8 Million Tonnes of Oil Equivalent. Refined petroleum energy accounted for 37% of the total energy mix, followed by coal (31%), gas (19%), and renewable energy (13%), such as hydro and geothermal energy.

On the demand side, the total final energy consumption (without traditional biomass) is used to meet the needs of the transportation sector (40%), followed by industry (36%), households (16%), commercial (6%), and other sectors (2%) (National Energy Council, 2019). Under the utility sector, the capacity of power plants up to 2018 was around 64.5 GW, a rise of 3% compared with 2017. Most of the installed capacity of power plants in 2018 came from fossil energy plants, especially coal (50%), followed by natural gas (29%), fuel (7%), and renewable energy (14%). Most of these power plants are managed by state-owned electricity companies, which is around 43.2 GW (67%), while independent power producers manage the other 14.9 GW (23%).

The Agency for the Assessment and Application of Technology's (2019) estimated projection shows that Indonesia's GHG emissions produced by power plant activities amounted to more than 40%, followed by transportation and industry, as shown in Fig. 2. The primary source of electricity in Indonesia is coal power, which is used in steam power plants. Compared with other fuel types, coal is favored in Indonesia because of the low-cost characteristics and the ease of extracting and transporting it (PricewaterhouseCoopers, 2016). Since most of Indonesia's coal is of poor quality, the energy sector is still the most significant contributor to Indonesia's GHG emissions. Given this strong link between coal-energy consumption and GHG emissions, seeking cleaner alternative energy sources is necessary to reduce Indonesia's emissions.

2.2. COVID-19 and energy-related emissions

The COVID-19 pandemic has been unprecedented, affecting multidimensional aspects, such as economic and environment. The direct effect of COVID-19 on economic variables has been empirically investigated already. Baker et al. (2020a) found a strong, negative effect of pandemic-induced economic uncertainty on the United States' real GDP. Ma et al. (2020) support this finding, showing a persistent negative effect of the pandemic on 210 countries. Baker et al. (2020b) show that the COVID-19 pandemic favored the volatility of the stock market compared with the effects of other previously known infectious disease outbreaks. Jordà et al. (2020) also reveal that pandemics decline the real interest rate in the long term. Sectoral studies show that the face-to-face service sectors, including tourism and retail, are the most affected by the COVID-19 pandemic (Nicola et al., 2020; Verikios, 2020).

However, COVID-19 also affects environmental aspects. The decline in economic activities, such as working in offices and lower production, can significantly affect energy consumption. Indeed, there is a positive correlation between economic growth and energy (Abdoli et al., 2015; Acaravci and Ozturk, 2010; Shahbaz et al., 2013). This conclusion implies that a decrease in economic activity can lead to a reduction in energy consumption. Such a decline mainly took place in the power sector; the transportation industry and offices were temporarily closed, leading to a significant drop in mobility (IEA, 2020). Besides the temporary cessation of industrial activity, the government's social restriction policies also reduced transportation activities, leading to lower energy consumption and lower refined petroleum demand. However, the increase in activities within houses has led to an increase in household energy consumption to a certain extent, particularly electricity and gas.

Such changes in energy consumption patterns can affect emissions levels, particularly those produced by the energy sector. The literature also shows that energy consumption is the main driving force of emissions growth (Coordinating Ministry for Economic Affairs & United Nations Development Programme, 2018; Wu et al., 2020).

Few empirical studies explore the effect of COVID-19 on energy consumption and emissions(Edomah & Ndulue, 2020) Social restrictions to limit the spread of COVID-19 have made people housebound, thus increasing household electricity consumption (Chen et al., 2020), while the industrial and commercial sectors have experienced a decline. Thus, the overall electricity consumption has declined. Using the demand variation index, Bahmanyar et al. (2020) show a decrease in national electricity consumption in the

European Union due to the social restriction policies. Abu-Rayash and Dincer (2020) reveal a fall in electricity demand by 1267 GW in Ontario in April 2020. Apart from electricity, a decrease in energy consumption was also seen in fuel and coal. Gillingham et al. (2020) show a short-term reduction in jet fuel consumption and gasoline by 50% and 30%, respectively, in the United States. Kanitkar (2020) uses the input–output method to show a decrease in coal-based energy use during the lockdown policy in India.

Regarding the emissions variable, most studies show a temporary reduction in emissions and pollution from lockdown policies in various regions. Rume and Islam (2020) note pollution reduction in several heavily industrialized countries during the pandemic, such as the United States, Canada, China, India, Italy, and Brazil. Wang and Su (2020) also show that the pandemic decreased pollution, as measured by the nitrogen dioxide (NO_2) concentration in the air, throughout China. Muhammad et al. (2020), Espejo et al. (2020), and Urrutia-Pereira et al. (2020) show similar results under the worldwide scope. Owing to the decline in energy consumption, Han et al. (2020) use the GDP scaling method to show that a decrease in coal use and cement production reduced CO_2 in China. In India, Kanitkar (2020) show a reduction of 15–65 $MtCO_2$ from a 26% reduction in coal use.

Gillingham et al. (2020) and Abu-Rayash and Dincer (2020) reveal a reduction in GHG emissions from a decrease in fuel and electricity consumption in the United States and Canada. The lockdown policy has even affected mercury concentrations in the atmosphere (Wu et al., 2020). Naderipour et al. (2020) show a decrease in Malaysia's GHGs and pollution during the lockdown period. Specifically, Razzaq et al. (2020), using quantile on quantile estimation, show a temporary decrease in ozone from an increase in COVID-19 cases in 10 American states. Besides ozone, Zhang et al. (2020) show a fall in nitrogen oxides (NO_x) and aerosol pollution during China's lockdown period. Forster et al. (2020) show the same results at the global level. Other studies show a decrease in different types of pollutants such as particulate matter (PM), CO, NO_2, and sulfur dioxide (SO_2) during the lockdown period in various countries (Baldasano, 2020; Sharma et al., 2020; Liu et al., 2020). Several studies specifically show a reduction in CO_2 emissions during the lockdown period (Gillingham et al., 2020; Le Quéré et al., 2020; Han et al., 2020).

Based on the explanation above, the direct effect on annual GDP, energy use, and emissions depends on the transmission control policy and how social distancing and lockdowns are implemented in certain regions. The indirect effect of the crisis is also determined through the shape of the recovery.

To support people affected by COVID-19 and battle a deep economic recession, countries have promised massive investments and stimulus packages. In particular, the European Commission introduced a €750 billion economic stimulus plan in Parliament on July 2020. The stimulus plan was accompanied by a revised proposal for the European Union's 2021–2027 budget (European Parliament, 2020). Indonesia also revealed a stimulus plan worth $47.6 billion. Experience has shown that both the depth and duration can be drastically decreased through anticyclical policy to trigger demand. Measures should also be taken to prevent spillover effects from triggering a systemic financial crisis (IEA, 2020). The stimulus may also lead to a rebound effect of GDP as well as energy and emissions. Thus, some studies suggest a green economic stimulus to recover the economy, offering jobs and rebuilding the economy toward a low-carbon society (Institute for Essential Services Reform, 2020). For instance, investment in green projects such as renewable energy, energy efficiency, and clean transportation projects should be made. The design of stimulus for COVID-19 recovery may determine the indirect effect of COVID-19 on emissions. Fig. 3 shows the transmission map among the temporary effects of COVID-19 on energy-related emissions. This mapping can be used to identify the effect of COVID-19 on CO_2 emissions.

3. Methods

3.1. Computable general equilibrium-indoterm

The general equilibrium analysis remains the most predominant method in assessing the effects on a wide range of topics, including investment (Lu et al., 2010), tourism (Gatti, 2013; Njoya and Seetaram, 2018), environmental policy (Das and Chakraborti, 2013; Freire-gonzález, 2017; Zhou et al., 2018), and energy (Farajzadeh and Bakhshoodeh, 2015; Gelan, 2018; Lin and Jiang, 2011). The CGE analysis is commonly used to assess the national effect of a pandemic, such as influenza and COVID-19. For instance, Barnett & Tait (2009) and Smith et al. (2011) use the CGE model to estimate the economic effect of the pandemic influenza and associated policies in the United Kingdom. The scenarios varied from the best-case, which assumed that the contained outbreak is only in China, to the worst-case, which assumed that the pandemic has spread in all countries and affected the local economy. Changes in trade cost, domestic demand, and productivity were mostly used as channels for scenarios. Compared with input–output analysis or econometrics, the CGE model is not widely used because of its complexity, but it is advantageous as a regional economic analysis tool (Partridge & Rickman, 2010).

IndoTERM is derived from The Enormous Regional Model (TERM), an inter-regional model of the Australian economy. TERM is a bottom-up CGE model explicitly created for using extensive regional data, but it is computationally effective (Wittwer and Horridge, 2007). The inter-regional bottom-up CGE model means that the national economy is an aggregation of sub-national economies. Unlike the multi-regional model designed as a top-down model, in the bottom-up model, for each commodity, without exception, the CGE has its equilibrium (market-clearing) for each region. Thus, prices for each commodity differ in each part. Using differentiated prices by region, we formulated specific shocks in certain areas. The main advantage of using IndoTERM is that it considers the inter-regional trade factor so that each region is assumed to be interrelated.

The equation in the IndoTERM model is a representation of the optimal behavior of rational economic agents. In such a case, both producers and consumers interact in a competitive market economy. As mentioned earlier, the interaction shapes both the demand and supply of commodities brought together in the market, and modeled as equilibrium, balance, or market-clearing. Generally speaking, the equality of demand and supply for economic agents comes from the microeconomic optimization solutions (cost minimization for companies and utility maximization for households). Economic actors are assumed to be price-takers, and producers operate in competitive markets without superior profit.

The IndoTERM model has been used to assess the regional effect of reducing transport cost (Horridge et al., 2016) and the regional effect of higher energy prices (Horridge, 2006). Several assumptions used in the model (Patunru and Yusuf, 2016) also state that each region's production sector is assumed to minimize production costs through constant elasticity of substitution (CES) technology. The CES form of the function implies that inputs can substitute each other, subject to the price and substitution elasticity. The cost minimization decision is derived from demand optimization for inputs. It is assumed that the demand equation is formed by economic agents such as firms, households, investors, and the government. Each of the agents plays its role in the economy. Since the full model is too large to be explained herein, a complete explanation of the model can be found in the studies of Horridge (2011) and Horridge et al. (2005). The TERM model was first for-

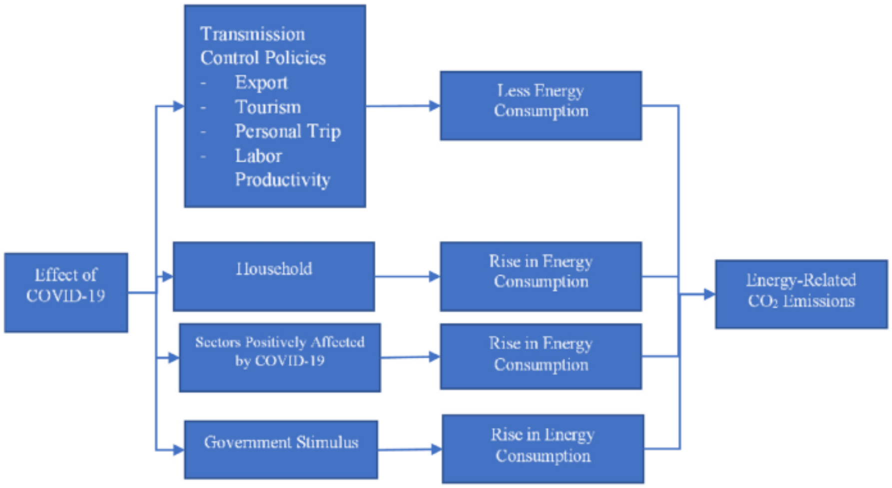

Fig. 3. Transmission from COVID-19 to Energy-Related Emissions.

mulated specifically for the case of Australia (Horridge et al., 2005; Wittwer, 2012), and then modified for Indonesia (Pambudi et al., 2006), China (Horridge and Wittwer, 2008), Brazil (Ferreira-Filho et al., 2010), Poland (Zawalinska et al., 2013), and South Africa (Stofberg and Van Heerden, 2015). In this study, we present only an overview of the model, since the theory and data structures are well documented in the literature.

Regarding the structure of the model, this study will elaborate TERM equations relevant to aggregate output and emissions production. The equations of the TERM model are broadly similar to those of other CGE models. For instance, in producing output, producers will consider how to choose the input combination. In this case, the output is expressed in the following equation:

$$X_{irt} = F\left(M_{cirt}, D_{cirt}, K_{irt}, L^{j}_{irt}, N_{irt}\right) \tag{1}$$

In Eq. (1), X is the output, D_c is the local intermediate input c, M_c is the imported intermediate input c, K is capital, L^j is the labor of type j, N is land, i is index for sector $i = 1, \ldots$,n, c is the index for commodity $c = 1, \ldots$,c, j *the* is index for labor type $j = 1, \ldots$,o, r is the index for region $r = 1, \ldots$,r, and t is the index for year.

Producers also choose a cost-minimizing combination of primary factor inputs. The production functions act as a constraint, which is structured by a series of CES "nesting" assumption. The cost-minimizing behavior of producers can be expressed as follows:

$$X_{irt} = \frac{1}{a^X_{irt}}\min\left\{\frac{1}{a^Z_{irt}}\left(\sum_{c=1}^{C}\gamma_{cir}\frac{\left(\tau_D D_{cirt}^{-\rho^A_{cir}}+\tau_M M_{cirt}^{-\rho^A_{cir}}\right)^{-\frac{1}{\rho^A_{cir}}}}{a^Z_{cirt}}\right)^{-\frac{1}{\rho^Z_{ir}}}, \frac{1}{a^Q_{irt}}\right.$$
$$\left.\left(\beta^K_{ir}\left(\frac{K_{irt}}{a^K_{irt}}\right)^{-\rho^Q_{ir}} + \frac{\beta^L_{ir}}{a^L_{irt}}\left(\sum_{j=1}^{O}\delta_{irj}\left(\frac{L^j_{irt}}{a^{Lj}_{irt}}\right)^{\rho^L_{ir}}\right)^{-\frac{\rho^Q_{ir}}{\rho^L_{ir}}} + \beta^N_{ir}\left(\frac{N_{irt}}{a^N_{irt}}\right)^{-\rho^Q_{ir}}\right)^{-\frac{1}{\rho^Q_{ir}}}\right\}. \tag{2}$$

In Eq. (2), α, β, γ, and τ denote the CES share parameters. ρ is the CES substitution parameter, where the elasticity of substitution $\sigma = 1/(1 + \rho)$. All as, except a^X, denote the specific-input-augmenting technical change parameter. a^X denotes the all-input-augmenting technical change parameter, while a^Z, a^Q, a^K, a^L, and a^N are the all-intermediate-input-, all-primary-input-, capital-, labor-, and land-augmenting technical change parameters, with subscripts i, r, and t representing the sectoral, commodity, and region indices. Eq. (2) implies that the change in output (e.g., by the decrease of global demand) will lead to a decrease in several inputs, such as labor (L) and local intermediate input (D). In this case, energy is an example of local intermediate input used by producers to produce output. ρ^Z, ρ^A, ρ^Q, and ρ^L stand for elasticities of substitution between domestic and imported goods for different intermediate inputs, between domestic goods and imported goods for similar intermediate inputs, between primary inputs, and between labor types, respectively.

The calculation of CO_2 emissions is also important, particularly those from the energy sector. For the calculation, data on detailed emissions by sector and source for Indonesia are required. However, the data are not available. Therefore, we use the detailed consumption of fossil fuel by source (coal, natural gas, and refined petroleum) in the energy unit reported by the Statistics of Indonesian Energy Balance. The amount of CO_2 emissions can be calculated from the data on fossil fuel consumption. Subsequently, the assumption that all energy users are facing the same price for energy is used. Later, from said assumption and the input–output matrix data with detailed energy consumption by various users (industries, households, government, investment, and export) and energy source, a matrix of CO_2 emissions by user and source can be derived. More specifically, the matrix can be expressed as:

$$E_{f,u,r} = \delta.\varpi_f.CC_f.\phi.X^E_{f,u,r,}\ X^E \subseteq X. \tag{3}$$

In Eq. (3), $E_{f,u,r}$ denotes the CO_2 emissions by energy type f, consumed by user u in region r, in tons. X^E is the quantity of energy consumption in a barrel of oil equivalent (BOE) unit, while $X^E_{f,u,r}$ is the quantity of energy consumption by energy type f, consumed by user u in region r, in a BOE unit. δ is a constant (44/12) that transforms carbon into CO_2 emissions. ϖ_f is the oxidation factor by energy type, or, in other words, a fraction of carbon oxidized. CC_f is the carbon content of energy type f in ton of carbon per Gigajoules (tC/GJ). ϕ is a factor to convert BOE to Gigajoules. Data on the quantity of energy consumption by energy type ($X^E_{f,u,r}$) are obtained from Statistics of Indonesian Energy Balance 2003, while ϖ_f, CC_f, and ϕ are obtained from the International Panel on Climate Change database.

Several datasets from Indonesian ministries, government agencies, and research organizations were used to construct the IndoTERM database. Data obtained from the Ministry of National Development Planning are supplied in the table and inter-regional input–output table from the year 2010. These tables are used to build regional shares. Data sourced from Statistics Indonesia include national labor force survey data, value-added manufacturing sectors of large and medium-size, and the province's GDP. The national labor force survey data are critical to construct a wage bill by occupational classification, sector classification, and regions. Agricultural data such as production and prices of farm commodities by provinces from the Ministry of Agriculture were also used to construct regional shares and aggregate individual commodities into broader categories from the input–output table. Finally, the database also uses export and import data by provincial ports obtained from the Center for Economics and Development Studies, Padjadjaran University and elasticity data from the Global Trade Analysis Project database. The basic model uses macroeconomic data by region/province and also nationally until 2014. For this study, the realization of the regional and national macro data are updated to 2015–2019. Detailed data source and unit are explained in the supplementary data file.

3.2. Model simulations

The simulations reflect the behavioral changes brought by the COVID-19 pandemic on the economy using several mechanisms. The first mechanism is the disruption of the global production chain to international trade, which is assumed to affect the economy through a decline in export. The decrease in demand for Indonesian products export is estimated for each commodity represented in the model. The magnitude of the reduction is influenced by the number of Indonesia's trading partners affected by the pandemic and each country's market share for Indonesia's export commodities. This mechanism will be simulated using data from Asian Development Bank (2020) analysis and the United Nations International Trade Statistics Database.

The economic effect will be affected by declination in international tourism activities. This decline is reflected by a decrease in exports of services related to tourism, such as hotels, restaurants, and transportations.

The third mechanism affecting the economy is the declination of personal trips. This mechanism is estimated using information from the decreasing activity pattern in the transportation sector (GDP) during the first quarter of 2020 and Google Mobility data to transit locations.

Finally, a declination of economic activities from various policy responses to combat the COVID-19 pandemic will reduce labor productivity. This mechanism is estimated by data from the Google Mobility report for each province in Indonesia.

We present two scenarios of IndoTERM simulation. It is assumed that the Indonesian government will implement a fiscal stimulus policy in both scenarios, as stated in Presidential Decree No. 72/2020. The presidential decree regulates the national budget to strengthen several sectors closely related to the COVID-19 pandemic. It amounts to 695.14 Trillion Rupiahs allocated to the health sector, government, small and medium enterprises, corporation finances, and business incentives, as shown in Table 1 (Ministry of Finance, 2020). The first scenario is pessimistic, assuming that the simulation indicators' percentage deviation will not return to the trajectory baseline, even with the fiscal stimulus policy. In this scenario, the economic recovery curve is L-shaped. The second scenario assumes otherwise; the economy will return to its trajectory baseline starting from 2025, with a V-shaped economic recovery curve. Both these scenarios will be compared with the baseline scenario. The baseline scenario, or the business-as-usual scenario,

Table 1
Allocation of Fiscal Stimulus in Presidential Decree 72/2020.

Aspect	Sub-Aspect	Fiscal Stimulus Allocation (in Trillion of Rupiahs)	Percentage (in%)
Public Health	• COVID-19 pandemic budgeting • Medical worker incentives • Death compensation • Premium relief for public health insurance • Taskforce financing • Tax incentives	87.5	12.59
Social Protection	• Family Hope Program • Daily necessities aid • Social aid • Pre-employment program • Electricity aid • Logistics aid • Direct cash assistance	203.9	29.33
Central and Local Government Financing	• Labor-intensive program financing • Housing incentives • Tourism recovery • Special allocation funds reserve • Economic recovery • Local loan facility • Expansion reserves	106.1	15.26
Small and Medium Enterprise Encouragement	• Interest allocation subsidy • Loan re-structuration allocation • Guarantee fee • Working capital loan • Income tax incentives • Investment financing	123.46	17.76
Corporate Financing	• *Re*-structuring of labor-intensive corporations • National equity capital • Bailout for working capital	53.57	7.71
Business Incentives	• Tax incentives	120.61	17.35
Total		**695.14**	**100**

Source: Presidential Decree No. 72/2020.

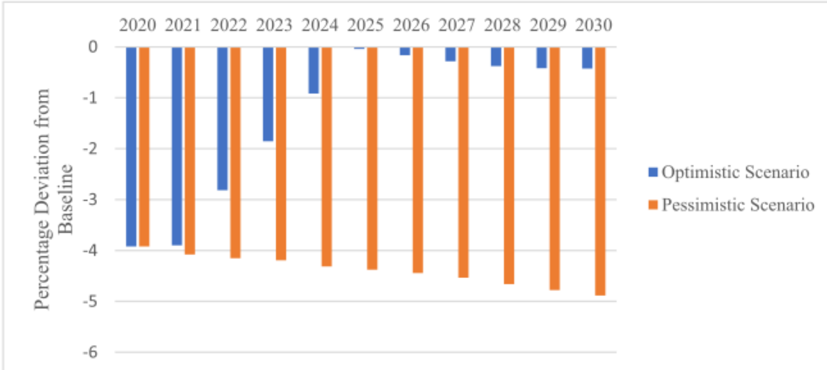

Fig. 4. Policy implication on national GDP
Source: Author's Calculation, 2020.

reflects the economy's dynamics without COVID-19 pandemic and fiscal stimulus.

4. Results and discussion

4.1. National analysis

We determine the effect of the pandemic and the implication of the stimulus policy based on the pessimistic and optimistic scenarios. The policy implications are reflected by macroeconomic indicators, energy consumption variables, and CO_2 emissions. For each indicator, a pessimistic and an optimistic scenario will be used. Both scenarios assume that a stimulus based on Presidential Decree No. 72/2020 is given to the economy only once, in 2020. The pessimistic scenario assumes that the economy will never recover to the trajectory baseline, while the optimistic scenario assumes that the economy will recover to the trajectory baseline, starting from 2025.

Fig. 4 shows a constant decline in national GDP percentage deviation from the baseline under the pessimistic scenario without signs of increasing at least until the year 2030. The optimistic scenario result shows a sharp increase in GDP growth, starting in the short run, followed by a small decline in the medium-to-long run. The GDP results show that the pandemic will restrain economic activities in the short run, reducing aggregate demand for products in general. However, the optimistic scenario shows a positive trend in GDP change. Its simulation results show that the one-shot stimulus given in 2020 will decrease the pandemic's negative effect on GDP by up to 4% in the long run compared with the pessimistic scenario.

The employment level shown in Fig. 5 shows a small increase above the baseline for both the pessimistic and optimistic scenarios in the short run, followed by a decrease several years after. This short-run decrease is sharper in the optimistic scenario, while the pessimistic scenario has a flatter decreasing curve. Both scenarios show an increase in employment level in the medium run, followed by another decrease several years later. Compared with the results in GDP and household income, employment clearly shows a different pattern. Since the model assumes full employment in the long run, both scenarios' employment levels will return to the equilibrium or baseline level. However, the magnitude of decrease in the optimistic scenario is more significant.

In the long run, the employment level in the optimistic scenario is still higher. This difference in the short-run condition of the pessimistic and optimistic scenario is from the difference in the assumption used in both scenarios. In the optimistic scenario, the economy is expected to recover back to the trajectory baseline in 2025. The model assumes that encouraging exports will save the economy faster than encouraging consumption to fulfill the recovery expectation. Hence, the sectoral composition will incline toward non-labor-intensive sectors, so that, in the optimistic scenario, the decrease in employment is more significant in the short run. However, exports will become stagnant in the long run, so that the opposite will apply to the long-run condition. In the pessimistic scenario, the economy is assumed not to recover to the trajectory baseline, so that the change in employment level stays negative (−0.173%) in 2030.

The changes in employment under the pessimistic and optimistic scenarios affect the changes in household income. Fig. 6 shows a decrease in household income under the pessimistic scenario. Starting from the medium run, the declining rate falls. In the optimistic scenario, household income shows a sharp decline in the year 2020–2021 by up to −3.558%, followed by a sharp increase several years after and starting to stabilize in the long run at around −0.453%. These simulation results for household income are relatively similar to the GDP simulation results. The extreme decline in household income under the optimistic scenario in the short run can be attributed to the change in the sectoral composition, as previously explained. The export-oriented economy in the short run drives the sectoral composition to shift toward non-labor-intensive sectors. Hence, the decrease in household income in the short run is more significant for the optimistic scenario than the pessimistic scenario. However, since the optimistic scenario assumes that recovery will occur in 2025, the optimistic scenario's long-run condition is far better than the pessimistic scenario that continuously decreases up to −2.768% in 2030.

Fig. 7 indicates a decrease, followed by an increase in coal-based energy consumption for pessimistic and optimistic scenarios. The optimistic scenario shows a smaller decrease, with the lowest point up to −0.982% in 2022, followed by an increase in the medium run.

In the pessimist scenario, the coal-energy consumption may drop till the lowest point at −3.065% in 2025. The pandemic has declined Indonesia's electricity demand, mainly from businesses and industries, although household demand for electricity is predicted to increase. Since most of Indonesia's power plants used to generate electricity are coal-powered, a decrease in overall electricity demand leads to a decline in coal demand. However, for both optimistic and pessimistic scenarios, coal-based energy consumption is expected to rise in the long run. The stimulus policy will ease the burden of industries and businesses from the pandemic. As stated in Presidential Decree No. 72/2020, the government has

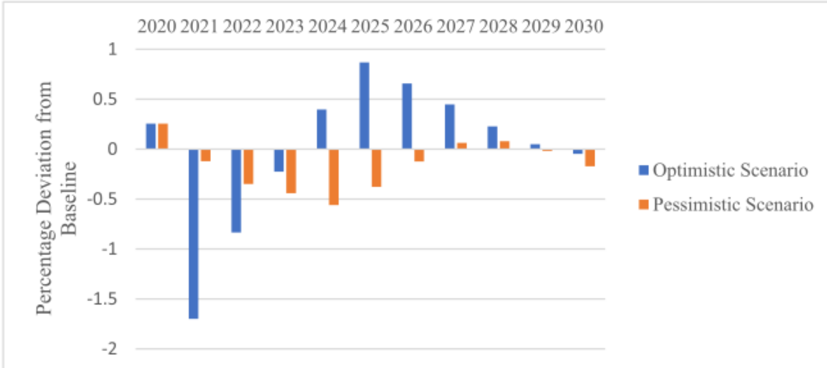

Fig. 5. Policy implication on employment
Source: Author's Calculation, 2020.

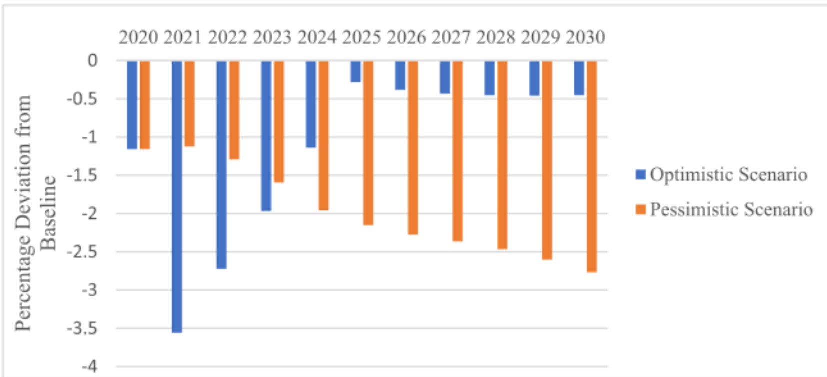

Fig. 6. Policy implication on household income
Source: Author's Calculation, 2020.

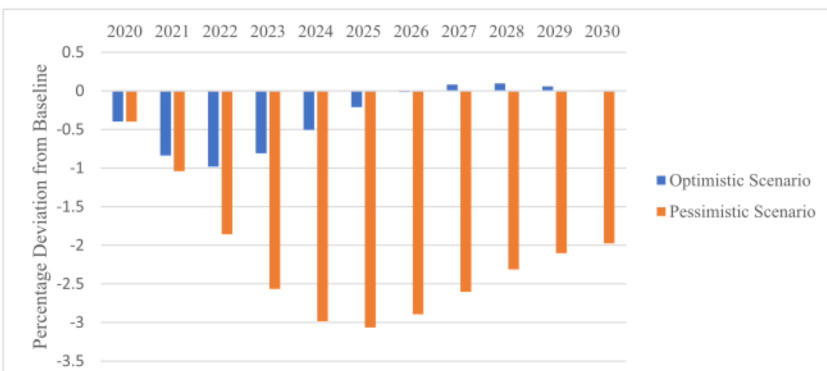

Fig. 7. Policy implication on coal-based energy consumption
Source: Author's Calculation, 2020.

allocated 123.46 Trillion Rupiah to boost small and medium industries' activities, 53.7 Trillion Rupiahs for corporate financing, and 120.61 Trillion Rupiahs for business incentives.

Fig. 8 shows a decrease in natural gas-based energy consumption in the short run, followed by an increasing trend in the long run for the pessimistic scenario and a slightly declining trend in the long run for the optimistic scenario. In terms of natural gas-based energy consumption, the optimistic scenario is better than the pessimistic one, starting in 2025. The optimistic scenario shows a consumption level slightly above the baseline. Compared with the decline in coal-based energy consumption, the effect on natural gas-based energy consumption is less severe. There are several natural gas-powered power plants in Indonesia, although the number is low compared with coal-powered power plants. Natural gas energy is mainly used in activities highly related to food and beverage industries, namely, restaurants, hotels, and tourism

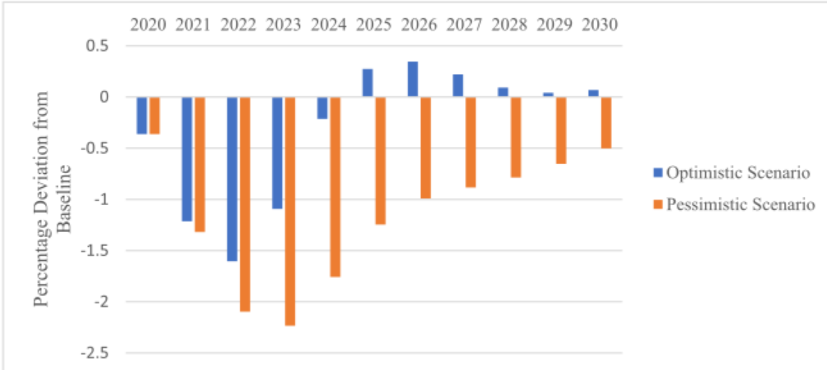

Fig. 8. Policy implication on natural gas-based energy consumption
Source: Author's Calculation, 2020.

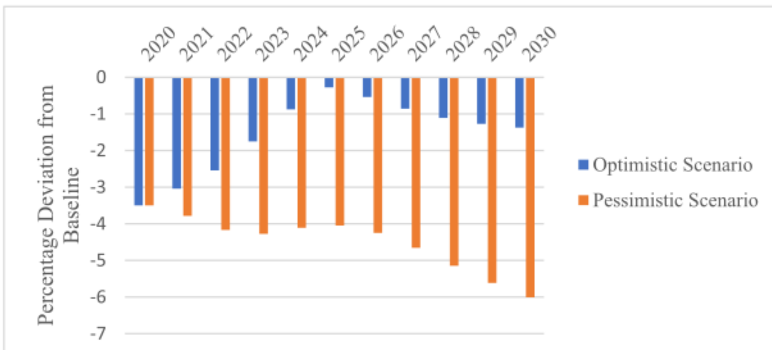

Fig. 9. Policy implication on refined petroleum energy consumption
Source: Author's Calculation, 2020.

in general. Since natural gas is only intensively used in these activities, a lesser effect from the pandemic is expected. Moreover, the stimulus policy component allocated particularly to boost small and medium industries' activities helped reduce these industries' effects. The latest data on small and medium-sized industries in Indonesia show that the number of small and medium-sized sectors engaged in the tourism, hotel, and restaurant sector is the second largest after the agricultural sector (Bank Indonesia, 2015).

Fig. 9 shows a clear difference between the two scenarios for refined petroleum energy consumption. The pessimistic scenario shows a decreasing trend throughout time. In contrast, the optimistic result shows an increasing trend in the short-to-medium run, followed by a slight decrease in the long run. Refined petroleum energy consumption highly correlates to mobility and transportation. Most of Indonesia's policies, especially at the local level, are mobility restriction policies to prevent people from going out of their homes.

Moreover, many industries and businesses, particularly in the services sector, implemented the "work from home" policy, with only personnel working in highly essential sectors allowed to commute to work. These policies have affected refined petroleum energy consumption the most, since the demand for transportation and mobility are significantly reduced. Data from IEA (2020) show that curtailment in mobility and aviation accounts for nearly 60% of global oil demand. International road transport activity was reduced to almost 50% and aviation activity was reduced to below 60%. Similar results are obtained by Norouzi et al. (2020). The stimulus policy is expected to have little influence on refined petroleum energy consumption, since none of the components of the policy focus on the transportation and mobility sector directly.

The CO_2 emission levels shown in Fig. 10 reveal a constant declining trend under the pessimistic scenario, while the optimistic scenario shows a more dynamic trend. The CO_2 emission level increased during the short-to-medium run, followed by a slight decrease from 2025 to −0.09% in 2030. Meanwhile, in the pessimistic scenario, the CO_2 emissions drop to −0.58% in 2030. These results show that the pessimistic scenario is better in terms of environmental indicators than the optimistic one. Several other studies also state that the decline in CO_2 emission levels depend on the level of fossil fuel consumption reduction, mainly coal-fueled energy (Han et al., 2020; Rume and Islam, 2020; Wang and Su, 2020), since many of the most significant industrial countries in the world, such as China, India, and Japan, are also the most significant coal-fueled energy users. Compared with the scenario results in the GDP's graph, the decrease in CO_2 emissions shows a relatively similar pattern. According to Hastuti et al. (2020), more than a 50% of the change in CO_2 emissions was due to a rise in GDP. Thus, it is expected that the CO_2 emissions decrease pattern will follow the GDP decrease.

4.2. Regional analysis

Fig. 11 shows the pessimistic and optimistic scenarios for GDP. The former implies that the economic effect of the pandemic is

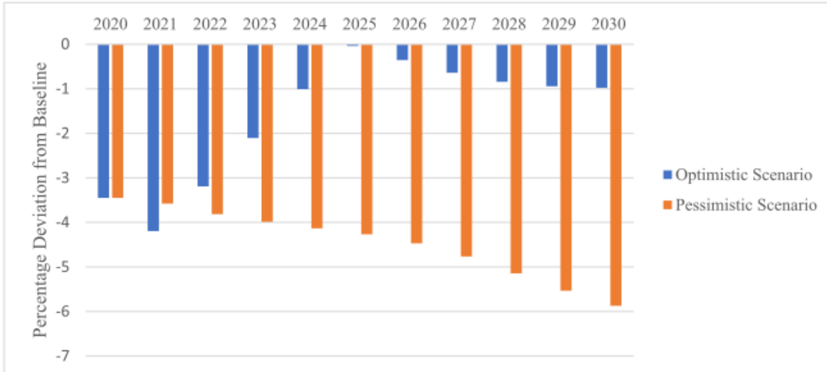

Fig. 10. Policy implication on CO_2 emissions
Source: Author's Calculation, 2020.

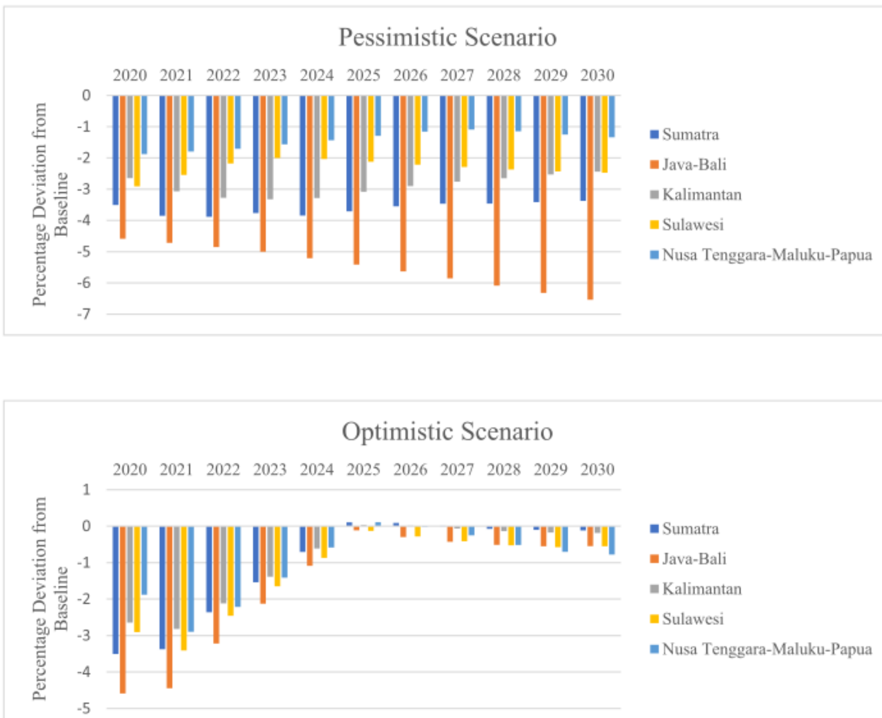

Fig. 11. Policy implication on regional GDP
Source: Author's Calculation, 2020.

sectoral-biased. The first case of COVID-19 in Indonesia was reported in the Java-Bali region, and the disease began to spread rapidly soon after. It is estimated that the Java-Bali region suffered the most economic effect from the pandemic since it has the densest population in Indonesia. It also has the most important hubs and nodes of connection to other parts of the country. The second most affected region is Sumatra, which is also the second most densely populated region. Under the pessimistic scenario, the economic effect of the pandemic shows a decreasing trend for every region in the short run, followed by varied trends that differ by region in the long run. For the Java-Bali region, the economic effect is expected to worsen in the long run for the pessimistic scenario, potentially reaching −6.537% in 2030. However, the optimistic scenario result shows that the severity of the economic effect for every region is lessening compared with the short- and long-run conditions. According to Norouzi et al. (2020), Wuhan in Hubei Province, China, the pandemic epicenter, experienced a GDP loss of up to -20%, far below the country GDP loss rate of −0.7%.

Fig. 12 shows the regional coal-based energy consumption trends. In the short run, Java-Bali and Sulawesi regions have the largest declines, although the Sumatra region suffers the most significant effect in the long run. Most regional trends follow the na-

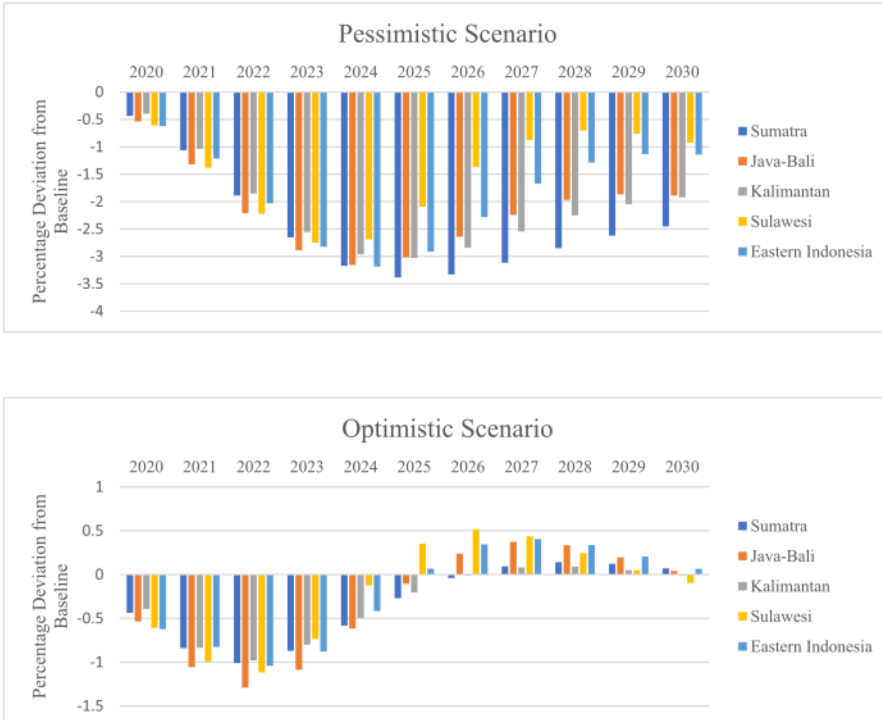

Fig. 12. Policy implication on regional coal-based energy consumption
Source: Author's Calculation, 2020.

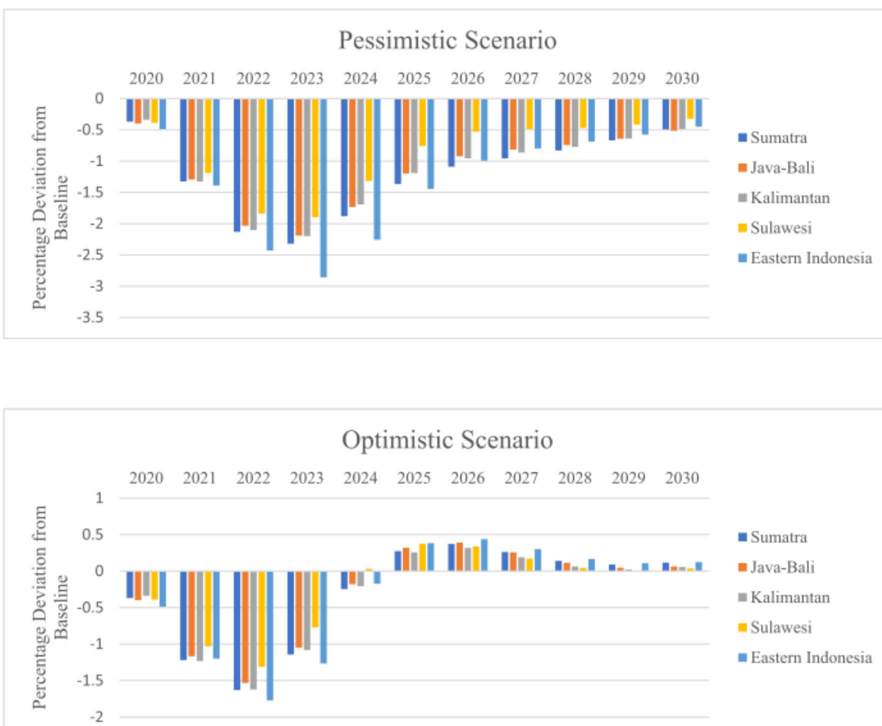

Fig. 13. Policy implication in regional natural gas-based energy consumption
Source: Author's Calculation, 2020.

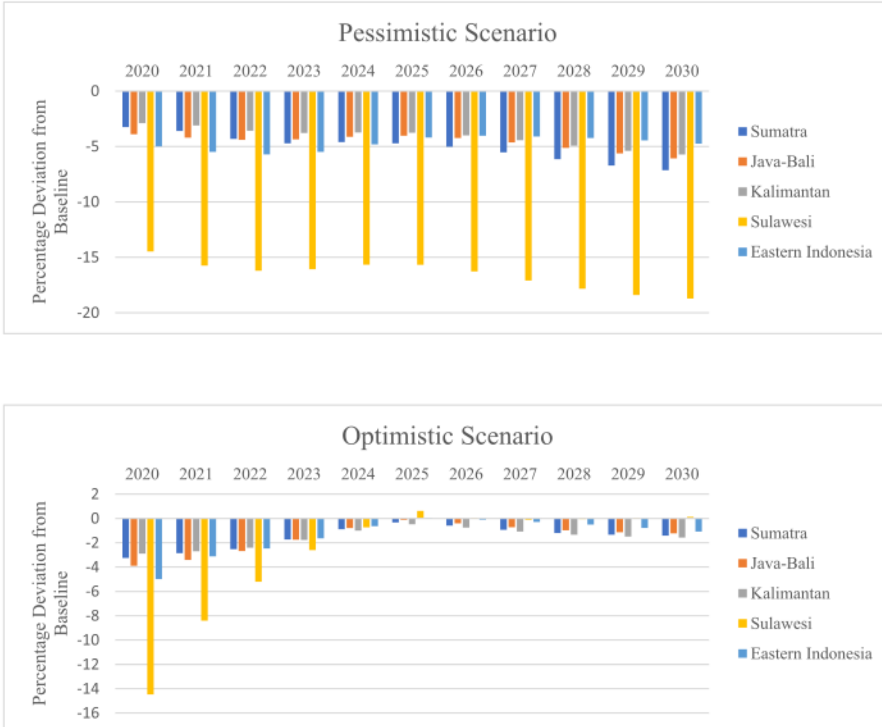

Fig. 14. Policy implication on regional refined petroleum energy consumption
Source: Author's Calculation, 2020.

tional trend. That is, the pandemic's effect on activities, particularly, industries and businesses, is the same for every region. The optimistic scenario also follows the short-run pessimistic trend. Nevertheless, starting from the medium-to-long run, the Sulawesi region shows a tremendous increase in coal-based energy consumption, with the highest point at 0.081%—higher than the baseline point in 2027.

Fig. 13 shows the policy implications for natural gas-based energy consumption. The result for the pessimistic scenario shows that eastern Indonesia (Nusa Tenggara, Maluku, and Papua) will experience the most severe effect in consumption, starting from the short-to-medium run. Since the region is highly dependent on the tourism sector, a significant decrease in natural gas-based energy consumption is expected. However, since most industries engaged in the tourism sector are small and medium-sized enterprises, East Indonesia's long-run effect is likely to weaken because of the stimulus policy. In the optimistic scenario, starting from the medium-to-long run, eastern Indonesia will increase consumption. That is, the stimulus policy will boost activities of small and medium-sized enterprises, particularly in the tourism sector.

Fig. 14 shows the pessimistic and optimistic scenario results in refined petroleum energy consumption for each region. The pessimistic scenario shows the highest decrease in refined petroleum energy consumption for the Sulawesi region. Over the years, eastern Indonesia shows an increase, while Sumatra, Java-Bali, and Kalimantan show reductions. Thus, their regional trends mostly follow the national trend, given reduced mobility in these regions from the COVID-19 protocols. The decrease in tourism activity and personal trips also causes related economic sectors, such as transportation and trade, to experience contractions. These contractions will further decrease refined petroleum energy consumption, mostly in terms of water transportation in the Sulawesi region. However, in the optimistic scenario, consumption, especially in the Sulawesi region, is expected to recover quickly and stabilize at the baseline level. A study by Norouzi et al. (2020) in China shows that the pandemic significantly reduces oil demand. Hubei Province, the center of the COVID-19 outbreak, experienced the lowest refined petroleum energy demand compared with the expectation. Both the Hubei Province in China and the Sulawesi region in Indonesia are vital to their respective country's transportation network. Wuhan, the first city to experience the crisis, is also one of China's most prominent transportation hubs (Norouzi et al., 2020). The Sulawesi region also has high connectivity to the other areas in Indonesia, particularly eastern Indonesia.

In Fig. 15, CO_2 emissions in the pessimistic scenario follow a similar trend as GDP, especially in the Java-Bali and Sumatra regions. Since these regions are the largest users of coal-based energy, economic activities in these regions are the highest emissions contributors. Electricity usage by industries and businesses in the Java-Bali and Sumatra regions is the most significant contributor to emissions in Indonesia. This result is in line with Han et al. (2020), who show that provinces in eastern China, the center of activities in the country, experience the most decline in CO_2 emissions than areas in western China owing to lower coal consumption. Therefore, if policies restricting activities and movements are implemented, it is expected that emissions in those regions will substantially reduce, significantly contributing to overall emissions reduction, as shown by the optimistic scenario. Emissions from each region will substantially reduce in the short run, but the reduction almost returns to the baseline in the long run.

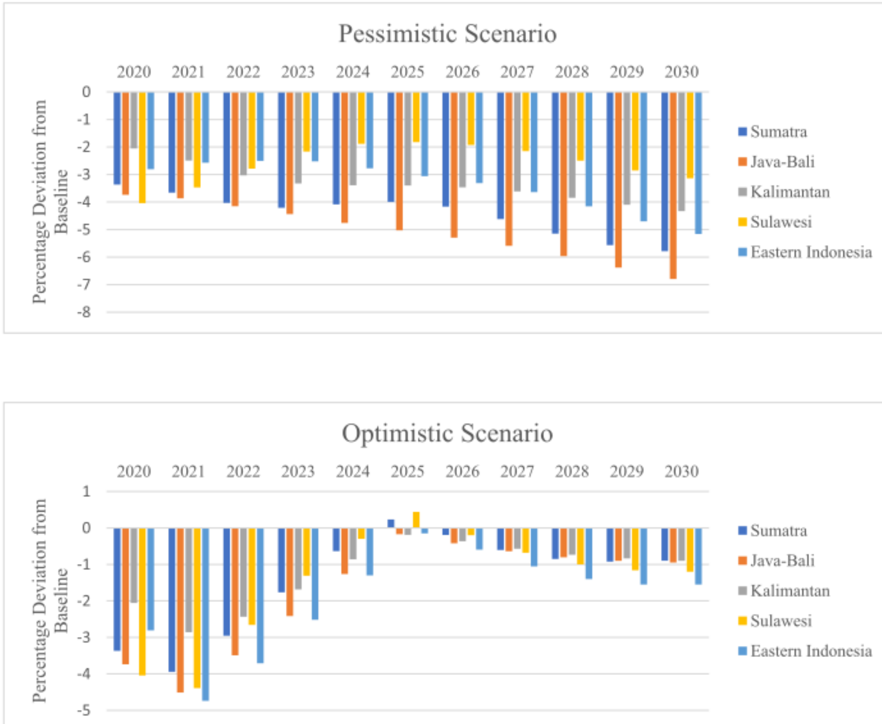

Fig. 15. Policy implication on regional CO_2 emissions
Source: Author's Calculation, 2020.

5. Conclusion

We analyzed the effect of the COVID-19 pandemic on the macroeconomic, energy consumption, and emissions indicators in Indonesia as well as the effect of the Indonesian government's stimulus policy based on Presidential Decree No. 72/2020. Besides the national scope of Indonesia, the COVID-19 effect was modeled by considering the regional heterogeneity of the effect. The productivity shocks measured and applied are region-specific. Using the IndoTERM CGE model, we assumed pessimistic and optimistic economic recovery scenarios. The pessimistic scenario assumed that the economy would not recover, while the optimistic scenario assumed that the economy would recover from 2025.

We find that the macroeconomic indicators, in general, perform worse in the short run under the optimistic scenario because the sectoral composition is inclined toward non-labor-intensive sectors in this condition. This scenario does yield better performance in macroeconomic indicators in the long run. Particularly, the Java-Bali region suffered the most economic effect from the pandemic, followed by the Sumatra region—the densest regions in Indonesia.

Consumption of energy fuels is the most affected by the pandemic, followed by coal-based energy. Refined petroleum energy consumption is positively related to mobility. The significant decrease in consumption implies that mobility restriction policies implemented by local authorities have been strongly affecting people's ability to take personal trips and reducing transportation demands. A sharp drop in coal-based energy consumption is also expected, since coal is the most significant electricity source in Indonesia. Although household electricity consumption has risen during the pandemic, the overall electricity demand is still low because of reduced business and industrial activities. Particularly, the Sulawesi region experienced the largest decrease in refined petroleum energy consumption, while the Java-Bali and Sumatra regions saw reductions in coal-based energy consumption. The reduction of consumption in the Sulawesi region can be attributed to the contraction in the transportation and trade sectors.

We also found out that the emissions reduction patterns are similar to the GDP decline pattern in the simulation results. This result is expected since GDP-generating activities are the most significant contributors to CO_2 emissions. In line with the national results, the regional results show that the Java-Bali and Sumatra regions are the highest contributors to emissions reduction, given the containment policies.

This study suggests that the environmental gain (lower pollution) from the COVID-19 crisis is temporary. This model is based on a neoclassical market economy assumption, which is plausible in most economic systems, allowing us to extend our outcomes, to various degrees, outside Indonesia. If COVID-19 triggers more environmentally sound economic development, then appropriate policy is needed for recovery. Returning the economy to its usual market channels will not lead to permanent environmental gains.

The results of the study have important policy implications as well. First, the Indonesian government must consider the long-term effect of the pandemic on the economy. Despite positive effects that the stimulus package may induce in the short run, particularly for employment and household income level, a greater negative effect may be persistent in the long run. To prevent this, the government must reformulate a more effective stimulus package. It has to stimulate household consumption to maintain purchasing power, preventing a further GDP decrease in the medium-to-long run. To maintain a secure level of employment, the government must create new and sustainable jobs, such as green jobs, to drive the labor force growth, and, thus, increase household income and consumption.

Second, the COVID-19 pandemic has created an opportunity for the central and local governments to promote low-carbon technology, clean energy transition, and sustainable development. It should educate businesses and consumers on energy efficiency. Besides economic recovery, the government must prioritize environmental recovery by centering low-carbon pathways in the stimulus package. Since the current stimulus package drives a rebound effect on energy consumption and emission, better allocation of the stimulus is necessary—for example, enhancing industry capacity to achieve low-carbon technology.

Third, the central and local governments must collaborate and coordinate when formulating a fiscal policy that equally prioritizes economic recovery and avoids the rebound effect, as explained above.

Nevertheless, this study has some limitations. First, it only estimates carbon emissions from fossil fuel consumption, and no other kinds of emissions such as local pollution (for instance NO_X and PM10). Thus, it may not represent the total effect on emissions. Second, the model used is recursive and dynamic, and, hence, the economic agents optimize their economic decision in one period. The link to the next period is through investment. An intertemporal model with agents that has a forward-looking expectation may be better. Third, future studies should consider adding an extra scenario to avoid emission returns to the pre-COVID-19 period; this includes adding fiscal instruments to address emissions such as carbon taxes and non-CO_2 emissions to the model.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors would sincerely thanks to the editor and two anonymous reviewers for their valuable comments to improve this paper. We acknowledge this research was partially funded by the Indonesian Ministry of Research and Technology / National Agency for Research and Innovation, and Indonesian Ministry of Education and Culture, under World Class University Program managed by Institut Teknologi Bandung. The first author would also like to thank United Nations Development Programme (UNDP) and Fiscal Policy Office, Ministry of Finance, Republic Indonesia for providing opportunities for discussion and supporting this research.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.spc.2021.06.003.

References

Abdoli, G., Farahani, Y.G., Dastan, S., 2015. Electricity consumption and economic growth in OPEC countries: a cointegrated panel analysis. OPEC Energy Rev 39, 1–16.

Acaravci, A., Ozturk, I., 2010. On the relationship between energy consumption, CO2emissions and economic growth in Europe. Energy 35 (12), 5412–5420. doi:10.1016/j.energy.2010.07.009.

Agency for the Assessment and Application of Technology. 2019. Indonesia Energy Outlook 2019: The Impact of Increased Utilization of New and Renewable Energy on the National Economy.

Anderson, K., McKibbin, W.J., 2000. Reducing coal subsidies and trade barriers: their contribution to greenhouse gas abatement. Environ Dev Econ 5 (4), 457–481. doi:10.1017/S1355770X00000279.

Asian Development Bank, 2020. The economic impact of the COVID-19 outbreak on developing Asia 9 (128), 1–14. doi:10.22617/BRF200096.

Barnett, T., & Tait, J. (2009). *The economy-wide impact of pandemic influenza on the UK: may 2014*. https://doi.org/10.1136/bmj.b4571

Das, K., Chakraborti, P., 2013. General equilibrium analysis of trade and environment under alternative market structure: a computable general equilibrium study for India 40 (September), 99–116. doi:10.1007/s40622-013-0003-3.

European Parliament. (2020). *covid-19 the eu plan for the economic recover*.

Farajzadeh, Z., Bakhshoodeh, M., 2015. Economic and environmental analyses of Iranian energy subsidy reform using Computable General Equilibrium (CGE) model. Energy for Sustainable Development 27, 147–154. doi:10.1016/j.esd.2015.06.002.

Freire-gonzález, J., 2017. SC. Journal of Policy Modeling doi:10.1016/j.jpolmod.2017.11.002.

Gatti, P., 2013. *Tourism,welfare and income distribution: The case of Croatia* 61 (1), 53–71.

Gelan, A., February 2016. Economic and environmental impacts of electricity subsidy reform in Kuwait: a general equilibrium analysis. Energy Policy, 2018 112, 381–398. doi:10.1016/j.enpol.2017.10.032.

Global Carbon Project. (2020). *Carbon Budget*.

Hastuti, S.H., Hartono, D., Putranti, T.M., Imansyah, M.H., 2020. The drivers of energy-related CO2 emission changes in Indonesia: structural decomposition analysis. Environmental Science and Pollution Research doi:10.1007/s11356-020-11414-7.

Horridge, J.M. (2006). *The Impacts of Higher Energy Prices on Indonesia ' s and West Java ' s Economies using INDOTERM, a Multiregional Model of Indonesia Working Paper in Economics and Department of Economics The Impacts of Higher Energy Prices on Indonesia ' s and West Java* . September.

Horridge, M., Yusuf, A.A., Ginting, E., Aji, P., 2016. IMPROVING INDONESIA ' S DOMESTIC CONNECTIVITY: AN INTER-REGIONAL CGE ANALYSIS 17, 1–31.

IEA. (2020). *Global Energy Review 2020*.

IMF. (2020). WORLD ECONOMIC OUTLOOK INTERNATIONAL MONETARY FUND The Great Lockdown. In *World Economic Outlook* (Issue May). https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020

Lin, B., Jiang, Z., 2011. Estimates of energy subsidies in China and impact of energy subsidy reform. Energy Economics 33 (2), 273–283. doi:10.1016/j.eneco.2010.07.005.

Lu, C., Zhang, X., He, J., 2010. A CGE analysis to study the impacts of energy investment on economic growth and carbon dioxide emission: a case of Shaanxi Province in western China q. Energy 35 (11), 4319–4327. doi:10.1016/j.energy.2009.04.007.

Maliszewska, M., Mattoo, A., Mensbrgghe, D., 2020. The Potential Impact of COVID-19 on GDP and Trade A Preliminary Assessment. Policy Research Working Paper 9211 (April), 1–24.

McKibbin, W.J., Fernando, R., 2020. The Global Macroeconomic Impacts of COVID-19: seven Scenarios. SSRN Electronic Journal doi:10.2139/ssrn.3547729.

Ministry of Energy and Mineral Resources. (2016). *First Nationally Determined Contribution Submitted to UNFCCC. November 2016*, 1–18. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Indonesia First/First NDC Indonesia_submitted to UNFCCC Set_November 2016.pdf

Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-jabir, A., Iosifidis, C., Agha, M., Agha, R., 2020. The socio-economic implications of the coronavirus pandemic (COVID-19): a review. International Journal of Surgery 78 (March), 185–193. doi:10.1016/j.ijsu.2020.04.018.

Njoya, E.T., & Seetaram, N. (2018). *Tourism Contribution to Poverty Alleviation in Kenya: a Dynamic Computable General Equilibrium Analysis*. https://doi.org/10.1177/0047287517700317

Ozili, K.N. (2020). *The growing impact of coronavirus on the global economy*. March, 3–5. http://theconversation.com/the-growing-impact-of-coronavirus-on-the-global-economy-132030

Shahbaz, M., Hye, Q.M.A., Tiwari, A.K., Leitão, N.C, 2013. Economic growth, energy consumption, financial development, international trade and CO2emissions in Indonesia. Renewable Sustainable Energy Rev. 25, 109–121. doi:10.1016/j.rser.2013.04.009.

Smith, R.D., Keogh-Brown, M.R., Barnett, T., 2011. Estimating the economic impact of pandemic influenza: an application of the computable general equilibrium model to the UK. Soc. Sci. Med. 73 (2), 235–244. doi:10.1016/j.socscimed.2011.05.025.

Verikios, G., 2020. Socio-Economic Planning Sciences The dynamic effects of infectious disease outbreaks: the case of pandemic influenza and human coronavirus. Socioecon Plann Sci 71 (March), 100898. doi:10.1016/j.seps.2020.100898.

Wittwer, G., & Horridge, M. (2007). *CGE modelling of the resources boom in Indonesia and Australia using TERM*. 1–16.

Wu, H., Xu, L., Ren, S., Hao, Y., Yan, G., 2020. How do energy consumption and environmental regulation affect carbon emissions in China? New evidence from a dynamic threshold panel model. Resour. Policy 67 (March), 101678. doi:10.1016/j.resourpol.2020.101678.

Yusuf, A.A., Resosudarmo, B.P., 2008. Mitigating Distributional Impact of Fuel Pricing Reform: the Indonesian Experience. ASEAN Econ Bull 25 (1), 32–47. doi:10.1355/ae25-1d.

Zhou, Y., Fang, W., Li, M., Liu, W., 2018. Exploring the impacts of a low-carbon policy instrument: a case of carbon tax on transportation in China. Resour. Conserv. Recycl. 139 (March), 307–314. doi:10.1016/j.resconrec.2018.08.015.

Effect of COVID-19 on energy consumption and carbon dioxide emissions in Indonesia

ORIGINALITY REPORT

9%	6%	6%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	sdgcenter.unpad.ac.id Internet Source	3%
2	Submitted to Fakultas Ekonomi Universitas Indonesia Student Paper	2%
3	S. Makhloufi, S. Diaf, Ch. Ould-Lahoucine, M.M. Hadjiat, K. Abdeladim. "Assessment of Algeria's electricity power demands during COVID-19 pandemic and wildfires incidents", Electric Power Systems Research, 2022 Publication	2%
4	ceds.feb.unpad.ac.id Internet Source	2%

Exclude quotes	Off	Exclude matches	< 1%
Exclude bibliography	Off		

Effect of COVID-19 on energy consumption and carbon dioxide emissions in Indonesia

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14