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Article

An assessment of the short-term impact of COVID-19 on economics and the environment: A case study of Indonesia

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An assessment of the short-term impact of COVID-19 on economics and the environment: A case study of Indonesia☆

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ABSTRACT

The COVID-19 pandemic has already made a significant impact on various sectors. No country was fully prepared to face this global pandemic, and Indonesia is no exception. For Indonesia, this pandemic shook not only the public health service system but also the economy. This study makes projections related to the impact of this pandemic on the Indonesian economy by utilising a computable general equilibrium (CGE) model. Additionally, we calculate the land needed to cover the demand for agricultural products, as well as the level to which emissions can be reduced. Our simulation shows that, along with every shock caused by COVID-19 to national supply and demand, Indonesia will be experiencing economic stagnation by 2021, with the gross domestic product (GDP) level 4–8% lower than the business as usual (BAU) level during the pandemic (2020–2021). The two sectors that will be hit hardest are the transportation and tourism sectors, making up a GDP loss ranging from 30% to 50%. During this stagnation, the agricultural sector is a potential sector for accommodating workers who have been laid off. The model also predicts that there will be a temporary land-use change that the farmers will prefer to use their land for food and horticultural commodities. As for emissions, our calculations show that the potential for emission reductions will be up to 8% by 2021, compared to the BAU level. However, the source of this emission reduction is not positive as it comes from the restriction of economic activity, and the growth in emissions from the industrial and waste sectors are still increasing rapidly, even during the pandemic. Thus, it is feared that there will be a very high spike in emissions when the pandemic ends, making the situation more challenging for Indonesia to achieve its emission mitigation targets. Furthermore, once the government introduces fiscal incentives to support the economy during the pandemic, the economic condition will be improved, although still not fully recovered. The model predicts that the government fiscal incentives may help to improve the GDP by around 1–3%, compared to when no incentive is introduced.
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1. Introduction

The COVID-19 pandemic has brought many changes to people's lives. All of the uncertainty that has arisen from the pandemic has transformed into a socio-economic crisis. The world bank projected that the pandemic would lead to around 5.2 per cent contraction in global GDP in 2020 (World Bank, 2021). The International Monetary Fund (IMF) even mentions this crisis as the worst economic downturn since the Great Depression (IMF, 2020). To avoid the collapse of health facilities and prevent the increase in deaths due to COVID-19, almost all countries are implementing social restriction policies and temporarily closing immigration gates. As a result, their economies have experienced both internal and external shock due to the decline in global economic activity.

Each country needs to ensure its people's welfare. Developed countries with more fiscal savings can provide sufficient fiscal injections to help communities while implementing social restrictions. Governments in developed countries also provide various policy packages that have been prepared during the transition period to the post-COVID-19 period, which we now know as the 'new normal'. However, developing countries are experiencing quite different conditions. Their governments need to divide up their very limited budgets to support health facilities and, at the same time, support an increasingly deteriorating economy. Their governments need to work harder to prepare the budget to support health facilities. A more thorough calculation and a larger budget also need to be prepared if a country decides to implement social restrictions. Developing countries are overwhelmed by the pandemic, and one of the countries in the Asian region that has experienced a significant economic impact is Indonesia.

Indonesia holds the highest number of the total case in the Southeast Asia region. As the biggest economy in the region, the Indonesian government's policies for handling the COVID-19 pandemic also brings about regional attention. The Indonesian government is determined to not choose total lockdown as an option to reduce the spread of COVID-19. As an alternative, the government has applied a social restriction policy to provinces and regions experiencing a high number of COVID-19 cases. In recent months, as vaccination rates have increased, the government has tried to loosen restrictions. However, the second wave appeared in June 2021; thus, the social restriction policy, especially on the islands of Java and Bali, was implemented again.

The Indonesian government has been reminded repeatedly by epidemiologists and public health experts to be careful in deciding to relax social restrictions, as it is feared that easing restrictions could result in a more serious pandemic wave. Considering the large population of Indonesia, there are still numerous people who have not been properly educated regarding COVID-19 and the health protocols that need to be implemented (Rakhmat, 2020). However, the Indonesian government is also concerned that the pandemic would threaten the economy. Since the first case of COVID-19 was discovered in Indonesia in March 2020, the government has claimed to have invested a large amount of the budget into supporting the public during the pandemic, especially during the enactment of the social restriction policy. This unexpected expenditure was a massive blow to the government budget. However, the fiscal injection was sufficient for Indonesia to maintain the economic situation the past year. Even though the Indonesian economy experienced a slight contraction towards the end of 2020, its performance has maintained itself quite well since then. However, given the high budget deficit during the pandemic, the government is worried that it will not be able to provide a more significant injection in the event of a more severe pandemic wave, especially if social restrictions need to be re-imposed throughout Indonesia.

Despite the rapid progress of vaccination in the country, uncertainty is still very high, especially considering the projected time gap until the global economy will fully recover from the pandemic. Additionally, there is still the possibility of new COVID-19 variants. If that happens, Indonesia may need to apply another social restriction, which is feared to hamper the economy even further; the government budget will not be sufficient to support people's lives. In addition, Indonesia is the country with the fourth-largest population in the world, so the government needs to ensure the availability of food for the people during global uncertainty (Dwiwahjono, 2020; Pemerintah Republik Indonesia, 2020; Preuss, 2020). Considering this fact, the government recently decided to convert some land into food cropland, including some peatland areas. This will bring serious post-pandemic environmental problems, especially since Indonesia has been experiencing many challenges in reducing emissions from the land-use change sector. It is considered that the opening of new agricultural land, especially on peatlands, will cause post-pandemic environmental problems and make it difficult for Indonesia to achieve its emission reduction target to reach net-zero emissions by 2060 (KLHK, 2021).

There is a lack of research and calculations of how big the impact of this pandemic will be on the economy and the environment, especially for developing countries like Indonesia. Therefore, using a computable general equilibrium (CGE) economic model, this study aims to project the impact of the COVID-19 pandemic on economic and environmental conditions in Indonesia. The government has also empowered all efforts to minimise the impact of the pandemic. Thus, we also simulate the impact of providing fiscal incentives (e.g. tax relief and subsidies) during the pandemic. Moreover, besides economics, the pandemic also affects the environment, such as the greenhouse gas (GHG) emission level. As the country with the most ambitious emission mitigation commitment in Southeast Asia, information regarding the pandemic's effect on emissions will be useful for arranging subsequent post-pandemic policies. Thus, we also include a simulation of the effects of COVID-19 on the emission level in this study.

2. Method and data

2.1. Model specification

This study is conducted by using CGE [Indonesia], which was constructed specifically to assess the Indonesian case. The country-specific model was designed to add more flexibility to adjust the parameters, depending on the national statistics and projection. The modelling and simulation in this study are run using GAMS 2.4.6 under the mathematical programming system for general equilibrium analysis *(MPSGE)* subsystem.[1]

The CGE model consists of several sets of the equation, but in the main principle, it follows the equilibrium principle, which means that under this CGE simulation, the total demand is always equal to the total supply. The equilibrium will be achieved through the price mechanism in the market. To describe that situation, inside the model there are several nested equations. In general, there are three main blocks set up in the model: the production block, the income block and the international transaction (export and import) block. Each block is connected by the market and interacts through the price mechanism (Fig. 1).

The production block represents the supply side of the economy. In this block, several sectors produce some output both for the international and domestic markets. All the producers are assumed to satisfy the profit optimisation. To produce goods, each sector may need input from other sectors. Thus, if there is a shock in one sector, then it may spread to another sector, as the input–output connection is possible between sectors. To produce goods/services, each sector will also need capital, labour and energy. In addition to those resources, land is a specific production factor for the agricultural sector. Therefore, in this model, the produced outputs need both energy and non-energy inputs. The connection between the energy and non-energy inputs connected by Leontief aggregation means that these energy and non-energy inputs cannot substitute for each other. Moreover, the composite between capital and energy are connected in the *Constant Elasticity of Substitution* (CES) function. We utilise this kind of connection to indicate the elasticity of substitution between various inputs.

This production block also holds an important role, as many policy shocks/interventions can be done in this block, such as the introduction of more advanced and more efficient technologies. Therefore, this model consists of two production blocks: production with existing technologies, and production with advanced technologies. The introduction of new technology in this modelling can be done in several ways, depending on the kind of technology introduced, but mostly through the update of fixed capital formation and a change in the efficiency parameter. As this model is recursive-dynamic, it will also calculate the total supply and demand when the new technology is introduced. For the sake of conciseness, some of the equations and the dynamic recursive process can be found in Appendix 1.

On the demand/consumption side are households and the government. There is a reciprocal relationship between household and production blocks. The household sector provides production factors (e.g., capital and labour), and they will gain some income by providing those factors. By utilising this income, the household will consume some goods provided by the production block and optimise its utility. Therefore, if shocks occur, they will be interrelated from the supply and demand sides. Another consumer is the government. Just like a household, the government consumes some goods produced by the production block. However, the government also has a function for 'welfare distribution' to the household. The government gathers taxes from households, and when needed, the government will redistribute this tax to households through subsidies or other transfer payments. Both the household and government share the same resources to be consumed, consisting of energy and non-energy goods.

The production sector is also connected to the international blocks that consist of exports and imports. This connection means that Indonesia may export some of its domestic products while importing some products to be supplied in the domestic market. As Indonesia is a small open economy country, any international supply and demand shock will affect the national economy.

As mentioned before, another important treatment in the CGE model is the existence of market equilibrium. This market equilibrium is achieved through the existence of a price mechanism: the price will always balance the supply and demand in the market. For example, if the model indicates an oversupply condition for a product in the market, that product's price will be decreased, and vice versa.

2.2. Data

2.2.1. Input-output table

The main data method used as the foundation for this model's formulation was the input-output table (IO Table). We utilised this dataset as it gives the primary information on the connection between supply and demand in the economy. The CGE [Indonesia] model for this study was constructed using the IO Table 2010, which classifies the economy into 185 sectors. A

[1] *MPSGE* is a modelling language specially designed for solving Arrow-Debreu economic equilibrium models. An equilibrium in these variables satisfies a system of three classes of nonlinear inequalities: *zero profit, market clearance and income balance*. This means that in equilibrium, a production activity operated makes zero profit, and any production activity that earns a negative net return is idle. Likewise, any commodity that commands a positive price has a balance between aggregate supply and demand, and any commodity in excess supply has an equilibrium price of zero.

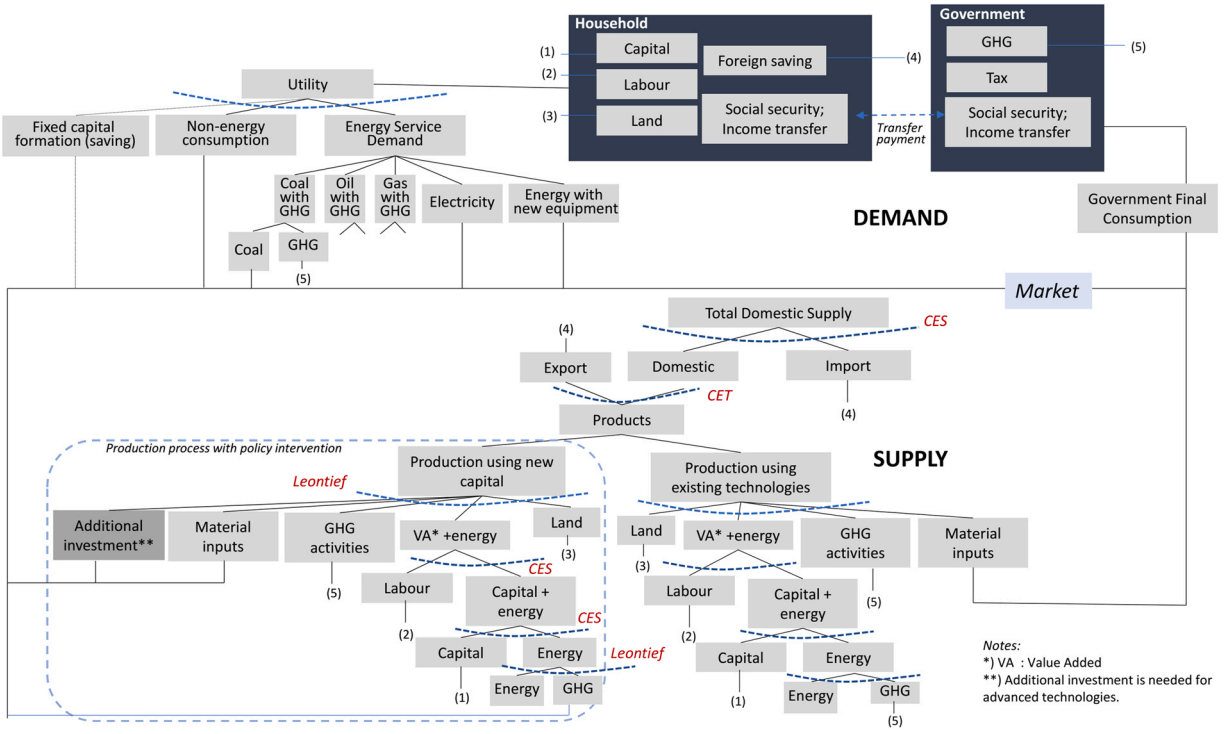

Fig. 1. Model structure of the study. *Notes:* CES: constant elasticity of substitution, CET: constant elasticity of transformation (substitution elasticity relation). CES is often used to describe the relation between price and demanded quantity (e.g. a lower price means higher demand). In contrast, CET is used to describe price and supplied volume relation (e.g., higher export price, higher export).
Source: Malahayati, 2019.

summary of the Indonesia IO Table structure can be found in Appendix 2. For this study, we performed aggregation/disaggregation of the sectors, and the result was only 40 sectors (Table 2B).

2.2.2. Other parameter settings

As mentioned before, our model was developed using Indonesia IO Table 2010, and we needed other supporting data and statistics to construct the model and run the simulation for the preferred target year. In this study, we chose 2021 as the target year. The decision to keep the simulation period short-medium was because we were considering the uncertainty of the COVID-19 pandemic situation.

The first parameter we needed involved economic growth statistics and projection. The main function of this information was to describe the country's ability to accumulate its capital. For this study, the actual data from 2010 to 2017 was taken from the official statistics (Badan Pusat Statistik, 2020). For the projection after 2017, it was assumed that economic growth would be around 5.1% from 2018 to 2021 under normal conditions. However, under the COVID-19 pandemic, economic growth needed to be revised. We used the economic growth assumption projected by the Asian Development Bank (ADB), which projected that Indonesia's economic growth would be around 2.5% in 2020 and back to around 5.0% by 2022 (Asian Development Bank, 2020a; Sawada, 2020).

Population data were needed for the labour projection in the model. In this study, as stated earlier, the population data was gained from Badan Pusat Statistik (2013). Since the objective of this study is to project the labour force, we used the working age range of the population data (15–64 years old).

To give a better description of the energy sector, we also added some information on Indonesia's annual final energy demand. With this information, we set the model to give a better description of the demand structure in Indonesia. Using statistics from MEMR-RI (2020), we calculated the average growth of final energy demand during the period 2010–2018 for resources such as coal (11.3%), natural gas (1.1%), oil (0.8%), town gas (11.7%) and electricity (7.5%).

We also considered the importance of land as a production factor for Indonesia. Especially during the pandemic, the Indonesian government has planned to expand the agricultural land to secure the national food stock. Additionally, the agriculture sector in Indonesia plays an important role in absorbing labour, especially in rural areas. The land itself is limited, so we needed to provide information regarding the total available land allocated for several functions such as cropland and forestland. Cropland can be utilised for several agricultural functions such as food crops, commercial plantations and livestock. Moreover, we treat land as input, and just like other inputs, substitution between lands is possible (e.g., land food crops can be utilised for

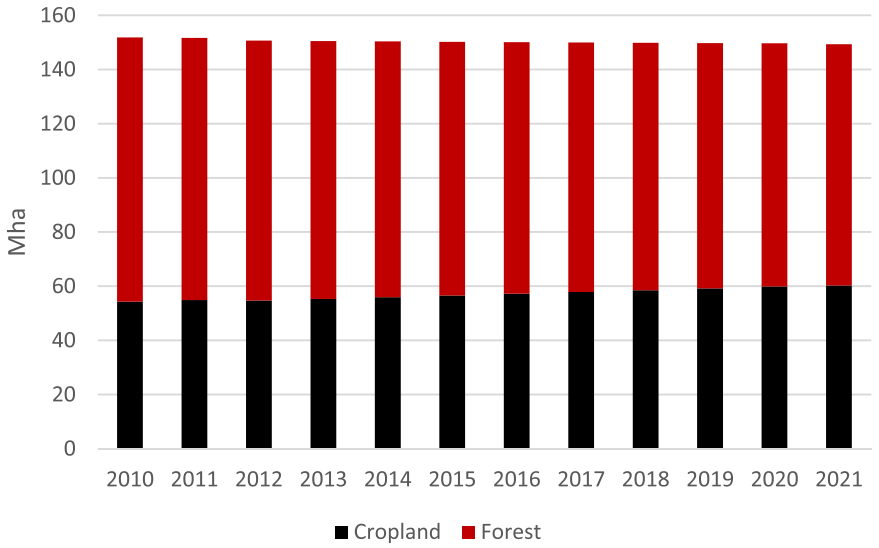

Fig. 2. Available land for cropland and forestland in Indonesia in 2010–2021. This cropland can be cultivated for agricultural activities (in this study, for food crops, plantations, wood, and livestock).
Source: Derived from (Boer et al., 2016).

livestock, etc.). Thus, we also needed to assume the 'elasticity of substitution' for the land inputs. To accommodate that, we made an assumption based on the crop productivity and production projection, as we assumed that crops with higher productivity will demand less land to achieve their production. The excess land gained from that yield improvement can be used by other agricultural sectors. In short, the model will calculate the demand for the cropland, depending on the production level, land availability, and crop productivity.

We used information from the Indonesia Deep Decarbonization Pathway Project (DDPP) for Forestry and Land Use of Indonesia (Boer et al., 2016). The available land for cropland is around 50–60 Mha, while around 90 Mha of land in Indonesia is assumed to be allocated and kept as forest areas (Fig. 2).

The productivity (yield) improvement for the food crops is around 0.3–0.9 ton/ha/year, while for plantations and wood, the yield improvement is projected to be higher – around 0.9–1.5 ton/ha/year, with the highest yield improvement value for palm oil plantations. There is no change in technology and yield under each scenario. The data on the crop production and total available land area for cropland and forestland area were gathered from the statistics published by the Ministry of Agriculture and National Statistical Bureau (*Badan Pusat Statistik*/ BPS) Moreover, for this study, we only considered the mineral land that can be exchanged for each other for economic activity.

2.2.3. Scenario and sensitivity analysis treatment

For this study, we set up three scenarios:

BAU: Business as usual (no COVID-19 pandemic, no policy intervention).

CM1: Existence of supply or demand shock caused by the COVID-19 pandemic.

CM1Tx: Existence of supply or demand shock caused by the COVID-19 pandemic + fiscal incentives from the government.

The main difference between CM1 and CM1tx is that in the latter we introduce the fiscal intervention provided by the government. This scenario addition is based on the fact that in 2020, the Indonesian government was already providing some fiscal incentives to maintain the consumption level during the pandemic. Since the first quarter of 2020, the Ministry of Finance started to reallocate around 5% of its budget for this subsidy. Most of these subsidies were allocated to support the small and medium enterprises (SMEs) and for social assistance that was distributed in the form of energy subsidies (including electricity subsidies) and staple foods aid (Kementerian Keuangan, 2020a).

As the COVID-19 pandemic sent significant shocks into the economy, we introduced these shocks to the CM scenarios. The macroeconomic shock was decided based on several literature and studies. In general, COVID-19, through some social restriction policies, will reduce the domestic consumption level of both households and the government. There is also an increase in unemployment due to the temporary closure of some industries. This increase in unemployment may reduce household demand. We also expect an investment drop triggered by economic contraction in general.

More specifically, there have been several sectoral shocks. In Indonesia, the tourism and transportation sectors are the two sectors most affected by the pandemic. The national and global social restriction policies have forced the tourism sector to close temporarily. Transportation, especially passenger transportation, has also stopped temporarily. There have also been shocks to other sectors such as the agriculture and energy sector. As the situation changes, we borrow projection results and studies,

mostly from the ADB and other relevant international institutions. The details of the shocks we applied in this model are summarised in the table below(Table 1).

Additionally, considering the high uncertainty of the condition due to the COVID-19 pandemic and as the CGE is very sensitive to the input and parameter setting, some sensitivity analysis is needed. In this study, a simple sensitivity analysis was done. We set the sensitivity analysis with the same scenario but with different economic growth assumptions. In the model, economic growth is connected with capital formation. We assumed that with higher economic growth, a country may be able to accumulate capital. Regarding the case of COVID-19, a country may be able to recover from the pandemic faster.

2.3. Study limitations

In addition to calculating the impacts of COVID-19 shocks on the economy, our simulation also calculated the effects of the pandemic on emissions. However, the emissions calculated from the land-based sector only considered the emissions from agricultural activity (e.g., rice cultivation, grazing, etc.). We did not calculate the emissions from the change in land use because we needed additional parameters and further adjustment, specifically related to the carbon stock. The emission from the land use change is calculated based on the carbon stock for each land type and vegetation. To make the emission calculation consistent and can be summed up with the emission from other economic activities, we need to adjust this carbon stock parameter and emission calculation to fit the sector classification on Indonesia IO Table 2010. The model for this study still cannot accommodate that process.

Moreover, the simulated result of the land area in this study describes the demand for land during the pandemic. We assume that the change in demand for agricultural products will have a high correlation with the change in land use in Indonesia, as stated in several studies (Malahayati and Masui, 2019; Popp et al., 2017; van Meijl et al., 2006). As mentioned in the method part, we set the total available land used for cropland and forestland (land endowment). The proportion of land demand by each crop will depend on the supply and demand of the crop in the market. However, as we have not provided a land-use change matrix[2] inside the model, we cannot provide a detailed simulation on land-use change in this study. This matter will need to be investigated further in later studies.

3. Result and discussion

3.1. General macroeconomic impact

We predicted that COVID-19 will slow down the economy compared to the normal situation (BAU level). Our simulation indicates that the total GDP would be lower by approximately 4.19% in 2020 and 7.77% in 2021 compared to the BAU level. This negative shock is caused by the stagnation in consumption, both household and government.

According to the prediction, the household consumption would slow down by around −3.40% in 2020 and −9.14% in 2021 compared to the BAU level. Moreover, the simulation forecasted government consumption of around −1.07% in 2020 and −7.07% in 2021, lower than the country's BAU level. The simulation also indicated a slowing down in investment growth compared to the BAU level. The loss would be around −1.51% in 2020 and −0.62% in 2021 compared to the BAU level. However, we found a slight increase in exports. This aligns with the Statistical Bureau's statement that Indonesia export remains positive, especially for agricultural products. However, as we also consider the government policies for easing import procedures for essential products during the pandemic (e.g. health equipment, staples, logistics), at the same time, the simulation predicted that there would also be a high import demand during the COVID-19 pandemic (Fig. 3).

In the next step of our simulation, we analysed whether the government's attempt by providing some fiscal incentives helped the sectors impacted by the COVID-19. As there was a significant increase in COVID-19 cases in Indonesia and further economic shocks were occurring, the government had already reallocated the national budget to provide subsidies and minimise the economic shock. The government had allocated 677.2 trillion IDR as an effort to handle COVID-19. Most of it has been for social protection (203.9 trillion), SMEs (123.46 trillion) and business incentives (120.61 trillion). Social protection incentives entailed energy subsidies and the provision of food for the poor (Kementerian Keuangan, 2020b). For this, the government had to make a fiscal adjustment by reallocating around 5% of its consumption (Kementerian Keuangan, 2020a).

Thus, we have observed that the economy has improved through this fiscal incentive. However, because we also assume that Indonesia is a small open economy, it is still further affected by the global economic condition, which might also hamper the economic recovery, even with the fiscal injection provided to support the national economy. Therefore, considering the global condition, the fiscal injection might not fully lift the economy to reach the normal condition. However, our simulation showed that the government's effort has been quite helpful in slightly lifting the economic condition during the pandemic. The general GDP loss was minimised by introducing the subsidies around − 2.76% in 2020 and − 6.18% in 2021 compared to the BAU level. Indeed, the fiscal incentive also improved the consumption level both for household consumptions (−0.37% [2020], −7.18 [2021] compared to the BAU level) and government consumption (−0.41% [2020], −5.30% [2021] compared to the BAU level).

[2] Land use change matrix/ land cover transition matrix/ land cover matrix is a matrix that is used to describe the conversion size of land-use types (for example, from forest land to cropland, swamp, residential, etc) in different period.

Table 1
Summary of shocks applied in this study.

Sectors	Shocks	Notes	Sources
General Macroeconomic			
Household consumption	-5%	Assumption of the drop in general domestic consumption in Asia during the pandemic	(Sawada, 2020)
Investment	-2%	Assumption growth in domestic investment in outbreak-affected economies	(Sawada, 2020)
Labour	-3%	The average value is based on several sources: Indonesia's Ministry of Finance project stated that there will be around 2.29–4.11% of unemployment increase. At the same time, the IMF project showed an approximately 2.20% increase in the unemployment rate.	(Bodamaev and Tuwo, 2020; IMF, 2020)
Sectoral			
Tourism (including hotels and restaurants)	-40%	Approximately 40% drop in demand for hospitality facilities and tourism in Asia	(Sawada, 2020)
Inland transportation	-7%	Following the Q-on-Q GDP drops in the transportation sector during the first quarter of 2020.	(Badan Pusat Statistik, 2020)
Other transportation	-40%	The assumption of the drop in average demand for aviation and sea transport. In Asia, the aviation industry has already experienced a 49.3% drop in demand since the start of the pandemic. For Indonesia, as the 'lockdown' has only been implemented in several major provinces, we assume the drop is approximately 40%.	(Zulkhibri and Sinay, 2020)
Energy			
* Coal	Export: − 8% Coal price: − 20% (2020), assuming the price increases by 50% by 2021.	Following the projection that the global coal demand is projected to fall by almost 8%. The fall in the coal price in 2020 globally is anticipated to be approximately 20%. We assume the condition will improve in 2021, and the price will increase at least by 50%.	(IEA, 2020; Nagle, 2020)
* Crude Oil	Export: − 5% Crude oil price: -65% (2020) assumed the price would be increased by 50% by 2021.	Following the projection that the global oil demand is down nearly 5%. The global world also anticipates a significant fall in crude oil prices. The price of crude oil has already fallen by around 65% since early 2020. We assume the condition will improve in 2021, and the price will increase by 50%.	(IEA, 2020; Nagle, 2020)
* Natural Gas	Export: − 2% Natural gas price: − 25% (2020), assuming the price increases by 50% by 2021.	Following the projection that the global gas demand is down around 2%. The fall in coal price in 2020 globally is anticipated to be around − 25%. We assume the condition will improve in 2021, and the price will increase by 50% at least.	(IEA, 2020; Nagle, 2020)
Agriculture			
* Rice	Household consumption: − 3%	In general, households will reduce grain consumption as the consumption of animal protein will also decline (feed consumption will be decreased).	(Chew, 2020)
	Government consumption: 10%	Median value as the government consumption of rice showed an increase of approximately 3–20% during the January–May period. The government will buy more rice for stock in the future. This rice will be used as a social assistant during the pandemic. Also, this rice will be reserved for national stock to prevent the dry season during the July–August period.	(Saleh, 2020)
* Horticulture	Household and government demand: 20%	As more people are cooking at home and have increased awareness of healthier foods, the demand for horticulture products will increase quite significantly. The government also seems to be stocking some horticulture products to anticipate future demand. We also follow the global trend, which shows a significant increase in horticulture products. This value is based on the increase in sales of horticulture products during the pandemic in Indonesia.	(Arumugam et al., 2020; CNBC Indonesia, 2020; Richards and Rickard, 2020)

(*continued on next page*)

Table 1 (*continued*)

Sectors	Shocks	Notes	Sources
* Commercial Plantations and Wood	Domestic demand for rubber, wood and other industrial plantation products: − 17%	Along with the temporary closure of some industries, the demand for some commercial products is decreased.	(Alika, 2020; CNBC Indonesia, 2020)
* Palm Oil	Export: − 30%	The export has reduced significantly as the global demand for crude palm oil has decreased. Fortunately, the domestic demand is still high as the product is required as input in the food and beverage industries.	(Alika, 2020; CNBC Indonesia, 2020)
* Livestock	Demand: 10%	Median value from the shock on livestock product consumption. Beef consumption will be reduced by 9–13%, while the consumption of poultry products will be reduced by 1–4%.	(Chew, 2020)

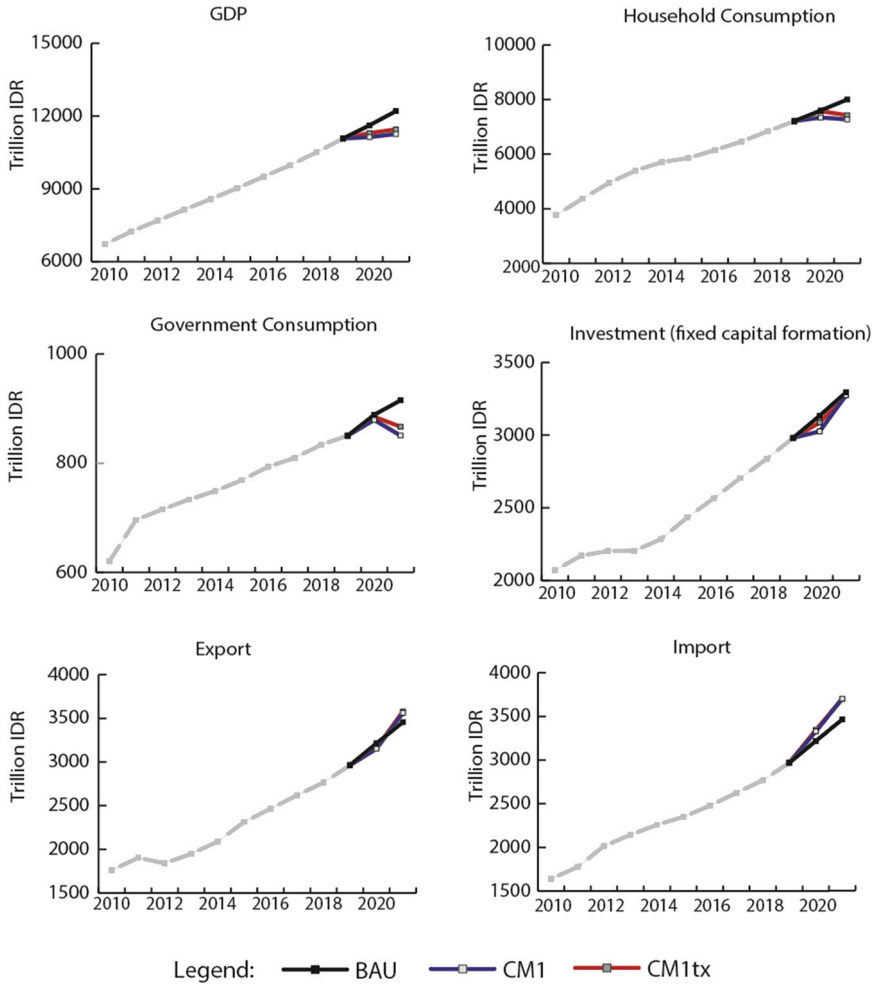

Fig. 3. Results of the simulation for macroeconomic indicators under each scenario.

3.2. Sectoral GDP

We then took a further look at the sectoral GDP. Although almost all sectors have been negatively affected by COVID-19, it is apparent that the tourism, transportation, and trade sectors have been impacted by the pandemic the most. Our simulation showed that by 2021, the sectoral GDP may drop by around 50%, 30% and 10% for the tourism, transportation, and trade sectors, respectively, compared to their BAU levels (Fig. 4). The tourism and hospitality sectors have been hit the most by the pandemic

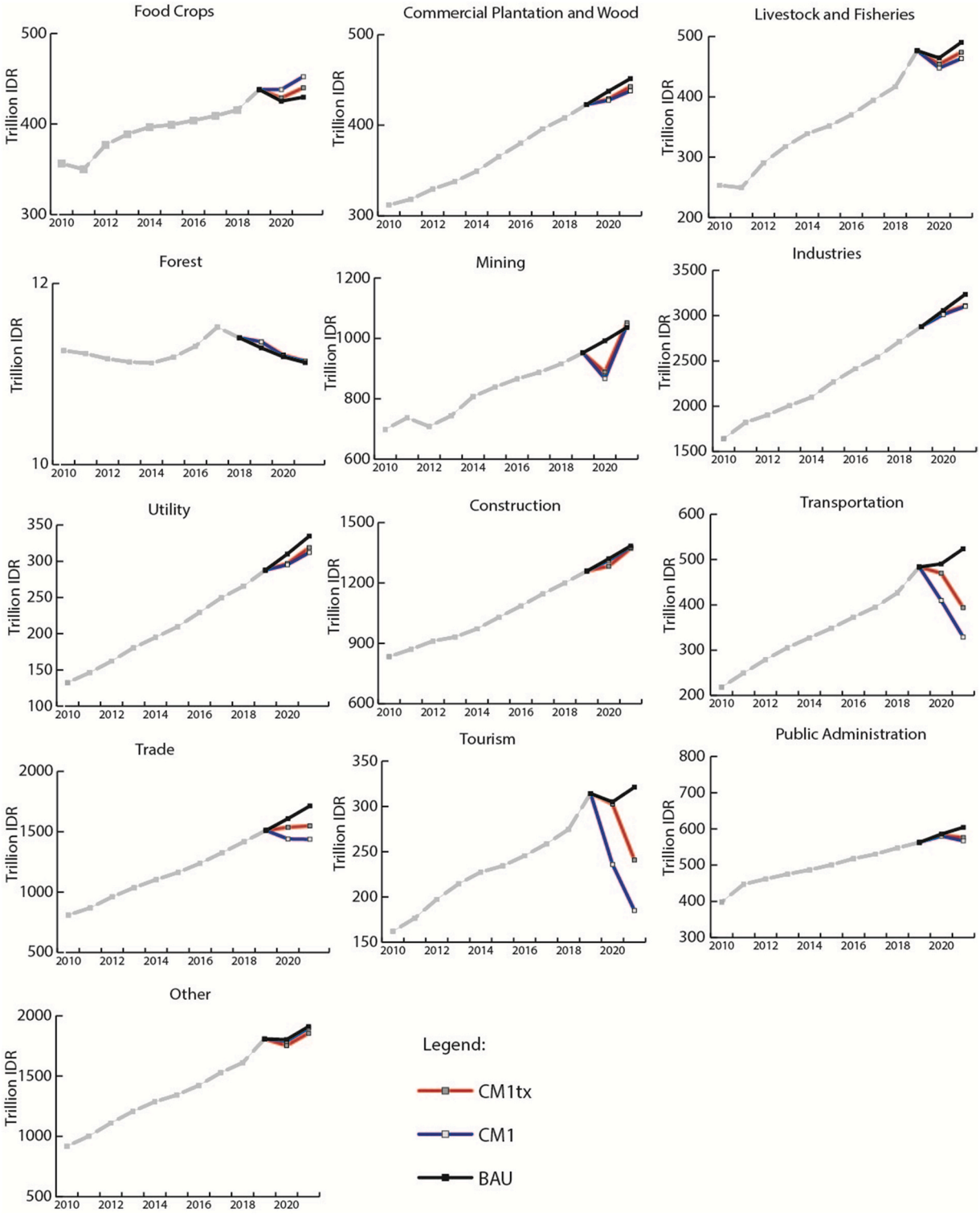

Fig. 4. Results of the simulation for sectoral GDP under each scenario *Notes: Food Crops include all carbohydrate sources* (e.g., *paddy, corn, cassava) and horticulture (e.g., vegetables and fruits). The detailed sector classification and grouping can be found in the Appendix (*Table 2B*).*

because the global social restrictions, lockdowns and long quarantine policies have significantly decreased the demand for tourism and forced some hospitality-related services such as restaurants and hotels to close their business. The transportation sector is also experiencing a significant GDP loss. Most transportation modes, especially non-inland passenger transportation (e.g., aviation and ships), have stopped operating due to global lockdown policies. Following the disturbance in the supply chain, the trade sector has also been negatively affected by the pandemic. Moreover, the trade sector has faced many difficulties during the pandemic from the drop of demand due to the social restrictions and because of the limited supply due to the disturbance in the global and national supply chain. Although the predicted loss of trade in sectoral GDP by 2021 is only around 10% compared to the BAU level, this matter is quite serious for Indonesia, as the trade sector is the sector that contributes the most to the national GDP and labour absorption.

Indeed, the other sectors were also experiencing negative shocks due to the pandemic, although not as big as those experienced by the tourism and transportation sectors. However, a slightly different trend can be found in the agricultural sector.

One of the most interesting results from our simulation is that it projected a slight increase in sectoral GDP of around 1–2% compared to the BAU level for food crops (including horticulture) during the pandemic. Although the economy is slowing down, there is still a demand for food, and there are several sources of demand for food crops. First is the government, as the government still buys staple foods from farmers to ensure that food stocks last throughout the year and to anticipate a decrease in supply. Other countries will also retain their national food stocks and reduce their imports. Thus, it is a strategic step for the Indonesian government to secure the food stock by buying from the domestic market. The second is from households; like in most other countries in Southeast Asia, public awareness and appreciation of agricultural products have increased in Indonesia (Gregorio and Ancog, 2020). Indonesia may experience higher demand for horticulture products such as fruits, vegetables, and biopharma products, along with increased awareness for healthy living. However, a similar trend cannot be seen in the commercial plantation and livestock sector.

Due to the global demand shock, we predict that there will be a reduction of approximately 2% in sectoral GDP for commercial plantations and wood compared to the BAU levels during the pandemic. This result is because Indonesia's exports are highly reliant on non-oil and gas products, especially plantation products such as palm oil. Therefore, this sector has been negatively affected as international demand for plantation and wood products has decreased since the pandemic. The trade is heavily affected by many obstacles to distribution. There are also cases where many products have to be diverted from one port to another or a different importing country, and it ends up being stuck and cannot be sold(OECD, 2017). However, the contraction is not major because there is still some demand from domestic industries. For example, food and beverage industries are predicted to survive during the pandemic and demand significant palm oil products as input that will help to maintain the demand for palm oil plantations.

Compared to the other agricultural sectors, the livestock and fisheries sectors are the sectors that hit the hardest during the pandemic, and there are several explanations for this negative GDP shock. Most of the literature agrees that the logistic problem related to social restriction policies is one of the primary reasons the livestock and fisheries are experiencing a negative shock. The social restriction has already disturbed the transportation sector that directly affects the supply chain, and ultimately delays the distribution of feed to breeders and product transport to the market (Patunru et al., 2020). As Indonesia still does not have sufficient storage for meat and fish, many breeders and fishers have chosen to limit or even stop their production. Moreover, livestock products in Indonesia have income elasticity higher than plant-based products. So, during the pandemic, as the people's income decreases, they will reduce the expenditure for livestock products and more likely to consume more plant-based products. Moreover, the pandemic also hampered the distribution of industrial raw materials and other logistics, making farmers' access to feed more limited and production costs soar (Ilham and Haryanto, 2020). Additionally, the COVID-19 virus is thought to spread through livestock products. Thus, consumers have started being more careful and have limited their animal protein consumption (Arora and Mishra, 2020; Siche, 2020). Moreover, as mentioned previously, the hotel and restaurant business have faced very serious shocks during the pandemic. The situation has made the demand for animal proteins from these sectors decrease significantly.

For the industry sector, our simulation showed that the pandemic might lower its sectoral GDP by 1–4% compared to the BAU level in 2020 and 2021, respectively. The loss is not too high because there is still a high demand for the food and beverages industries and the chemical and medical tools industries. However, of course, the logistic problem has hampered the growth of other industries.

For mining, the model predicts this sector will experience contraction during 2020. However, along with the recovery of global energy prices, the GDP from this sector will be recovered. The recovery of energy prices will have a significant impact on Indonesia's mining sector. This is because, although Indonesia plans to utilise its coal for domestic power generation, it still exports more than half of its coal and continues to make coal one of the main export commodities (Dewan Energi Nasional, 2017). Following the analysis of mining, we also examine the impact of the pandemic on the utility sector (i.e., water, gas, and electricity). The model forecast decreased sectoral GDP because the government decided to give more energy subsidies, specifically electricity. This subsidy implementation cut the income from the utility provider.

Furthermore, there is also a decrease in the GDP of the services sector. Public administration has needed to close or limit its services during the implementation of social restriction policies. There have also been shocks in other sectors (mostly services sectors). However, the shock is not as big as that to public administration services because there has been a significant increase in telecommunication services to support 'work from home'. Furthermore, some people are accessing more insurance services.

Finally, we can see how the fiscal incentives may have helped each sector deal with the pandemic. As we can observe from the simulation result for scenario CM1tx, the fiscal incentives potentially lift each sector's economic situation during the

pandemic. As the incentive is mostly targeted, the sectors impacted the most by the pandemic (tourism, transportation, and trade) have benefitted the most. The incentives are predicted to lift the sectoral GDP by 17%, 12% and 6% for the tourism, transportation, and trade sectors, respectively, compared to when no incentive is introduced. Moreover, the incentives are able to improve the sectoral GDP of other sectors by an average of 1–3%, compared to when no incentive is applied.

3.3. Labour force

Consistent with the macroeconomic result, the model predicted high unemployment, mostly in the transportation, tourism and trade sectors. Even if the government provides fiscal incentives, if the global demand for transportation and tourism remains low, the fiscal incentives will only help maintain the labour condition of these sectors through 2020, and there will still be a surge of unemployment in 2021. However, the unemployment rate will be lower by around 3% compared to when no incentive is available (Fig. 5). Although the government has already provided some fiscal stimulus for the tourism and transportation sectors, these sectors highly rely on people's mobility. As there is a significant limitation to mobility during the pandemic, these sectors are predicted to need more time to recover from the impacts of COVID-19. However, the incentives are quite helpful, as they can reduce the GDP loss due to the pandemic by 15–28% for the transportation and tourism sectors during the pandemic.

Moreover, we have detected the potential of the agricultural sector to absorb this unemployment into work in the agricultural sectors, as this sector is still a labour-intensive sector in Indonesia. When there are many layoffs in the other sectors, we predict that the unemployed people will go back to their hometowns and work on farms to make a living until they get new jobs after the economic condition improves. This is in line with Engel's law that when there is some shock on industry or any non-agricultural sectors, there will be a 'labour pull' from the agriculture sector. This agricultural labour pull also becomes an indicator of economic contraction (Alvarez-Cuadrado and Poschke, 2011). Although the model found that there will be a negative shock on the GDP of the plantations, livestock and fisheries, we expect that these sectors will still absorb more labour than other sectors.

We also still expect that the labour from industry will remain stagnant because the government is still attempting to maintain the availability of logistics. Thus, the government still allows labour in some essential industries (e.g. food, agricultural inputs and medical devices). Some industries are also still open but have converted their production. For example, most textile industries have converted their production from apparel into personal protective equipment for health workers. When the economy improves, Indonesia will boost these industry again and will need more workers to support their recovery.

Other sectors that will absorb labour during the pandemic are the utilities, construction, and other services sectors. As there are social restriction policies and policies on work and study, more people are spending time in their homes, increasing utility consumption. There is a similar explanation for services such as telecommunication services (e.g., internet) and health insurance services, which are predicted to increase. To support the sudden increase in demand, more labour for these sectors is required. As our model did not forecast a significant shock on construction sector GDP, this sector is still demanding, especially for residential construction and medical facility construction. Moreover, along with economic recovery, we predict the government will attempt to maintain this sector to support its target to boost infrastructure development.

In general, our model predicted that labour absorption will depend on economic conditions. The economy will improve slightly when fiscal intervention is available. Furthermore, along with economic improvement, there will be a 'labour pull' from agricultural sectors to return to the industry and other non-agricultural sectors, including trade, transportation and tourism. However, if we assume the demand for these sectors to be not fully recovered by 2021, these sectors will most likely still contribute to a high unemployment rate.

3.4. Land demand

The Indonesian government has planned to open more land for agriculture to ensure that food stocks last during the pandemic. This is also to prevent the shock of the international food supply. Moreover, from our model simulation, we predict that the available mineral land will be sufficient to support domestic food demand. Furthermore, as there will be demand shock on livestock, commercial plantations and wood, the demand for land for those sectors is projected to be lower. Therefore, the government can temporarily use those lands for food crops. Our model estimates that the land area for food crops will be higher than the BAU level if this occurs (Fig. 6). We also expect the forest area to increase slightly during the pandemic following the lower plantation and livestock sectors activity.

One important implication from this result is that the government does not require any more deforestation projects to fulfil the demand for agricultural land. As we assume the shock from COVID-19 is a relatively short-term shock, reallocating the available land will be a more sustainable option instead of opening new lands and increasing the deforestation rate.

We also see the impact of the fiscal incentives on the land area. The model predicts that the subsidies will boost the performance of plantations and livestock. Along with that, the land demand for these two sectors will increase, followed by some decrease in inland demand for food crops. This result is in line with the result of the macroeconomic simulation. When the fiscal incentives are introduced, they will help business resume throughout the country, and both the households and hospitality sectors (e.g., restaurants, accommodation, etc) might need more non-carbohydrate products. Therefore, the demand for cropland for livestock and commercial plantations will continue to increase.

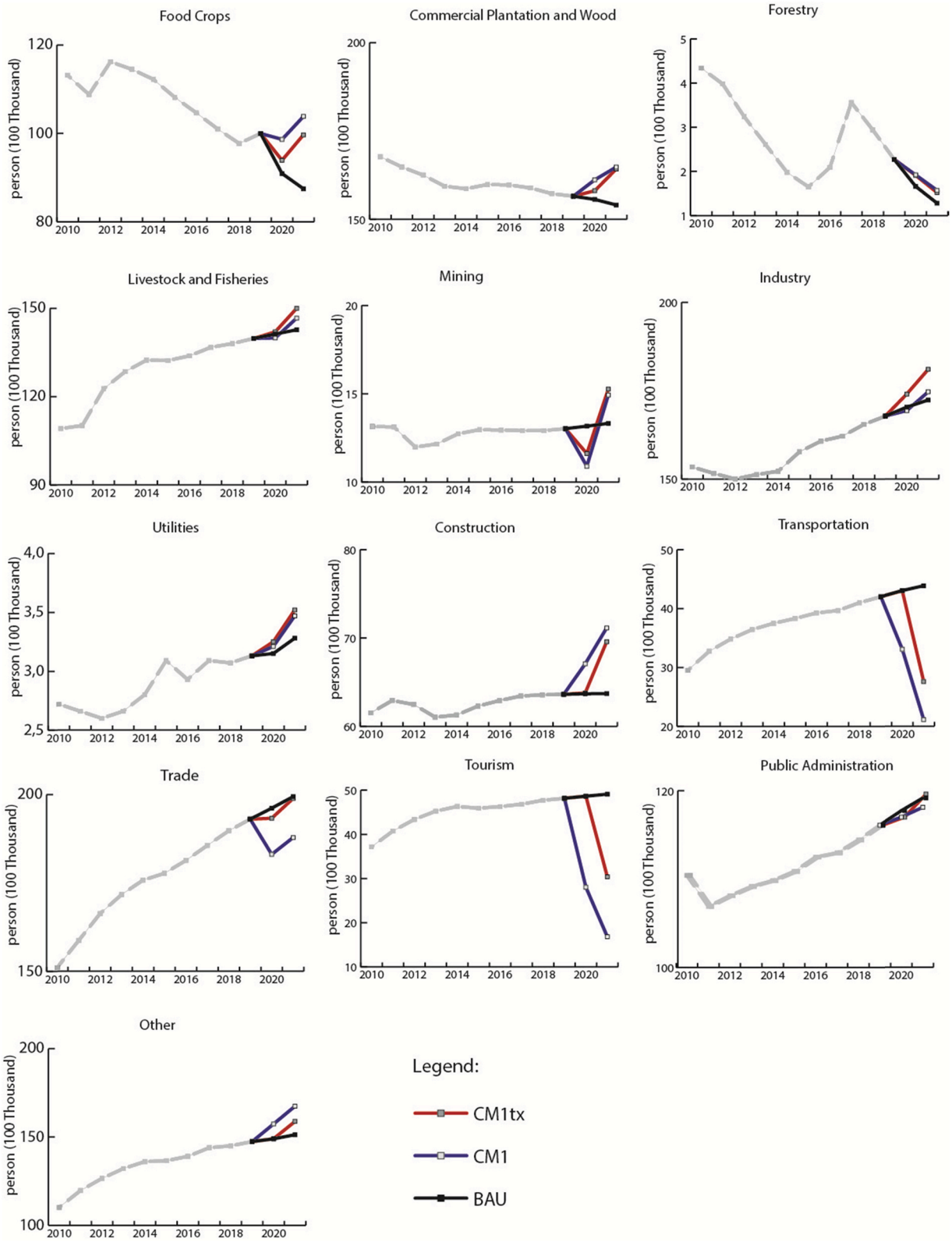

Fig. 5. Results of the simulation result for labour under each scenario.

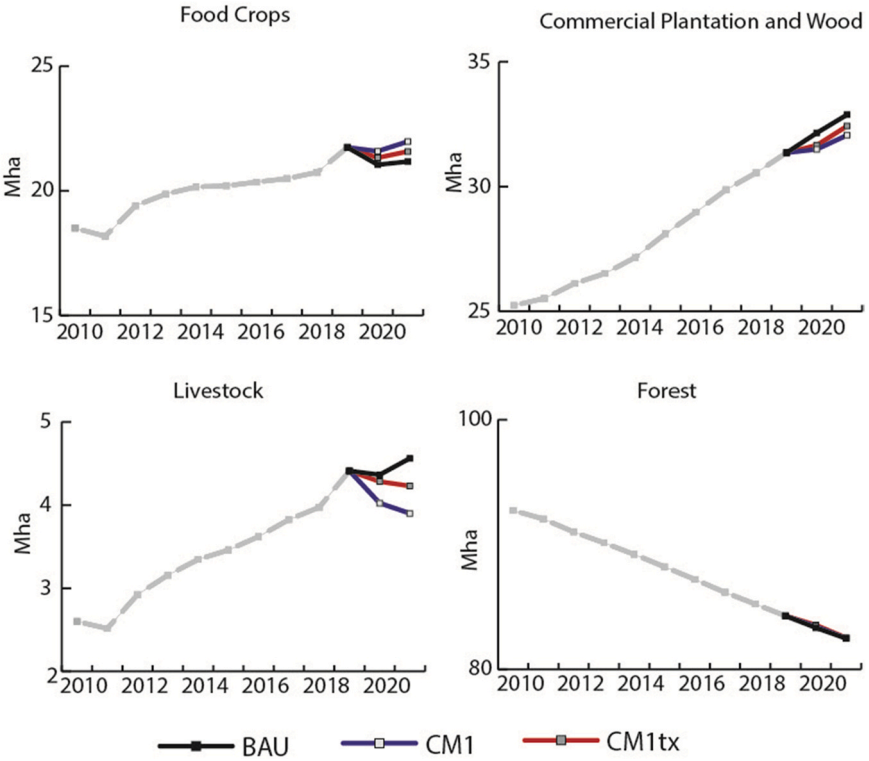

Fig. 6. Result of the simulation on demand for land under each scenario.

3.5. Greenhouse gases (GHG) emissions

Our model calculated GHG emissions from energy use and economic activity. The COVID-19 pandemic, followed by social restrictions, has already hampered most of the country's economic activity. Slower economic activity has implications such as a decrease in national emission levels. Compared to the BAU level, the total emission will decrease by approximately 6% in 2020 and 4% in 2021 (Fig. 7). The biggest reduction in sectoral emissions comes from the energy sector (2–6%), while there is still high growth of emissions for the industry and waste sectors, although their levels are lower compared to the BAU level.

As mentioned in the previous sections, subsidies will help Indonesia recover slightly from the economic shock caused by the COVID-19. The energy and SME subsidies will help the industry and enterprises to resume their economic activities. Therefore, our simulation results showed that by introducing subsidies, the emission level will increase slightly compared to without any fiscal interventions involved.

This result indeed looks good for the environment as the pandemic 'helps' to lower emissions. However, this emission reduction is temporary and not sustainable, as it is achieved through economic activity restrictions due to the pandemic. Additionally, the Indonesian government needs to anticipate a big spike in emissions. As can be seen from our simulation result, the actual emission reduction during the pandemic is lower than the economy's negative shock. If we look back at the simulation result for land use, the forest area might increase during the pandemic. However, that increase is so small that it cannot significantly impact emission reduction.

At the same time, the emission growth, especially for industry and waste sectors, is projected to grow rapidly, even during the pandemic. It is in line with the fact that some industries, especially the chemical and medical industries, have needed to boost their production during the pandemic. At the same time, although mobility and activity have been hampered during the pandemic, this has not significantly reduced waste accumulation, especially for medical waste, which has increased significantly during the pandemic (Renaldi, 2021). Seeing this trend, it is estimated that there will be a spike in post-pandemic emissions, which could hinder Indonesia from achieving its emission reduction target. This is especially important considering that Indonesia has ambitious emission reduction ambitions of 29% compared to the BAU level by 2030, with plans to even reach carbon-neutral conditions by 2060.

4. Sensitivity analysis: comparing several different growth scenarios

The output of the CGE model is very sensitive to its input. Therefore, we might obtain different results depending on the given input. Moreover, in the case of COVID-19, the situation is changing rapidly, as are the policies. There is also still very

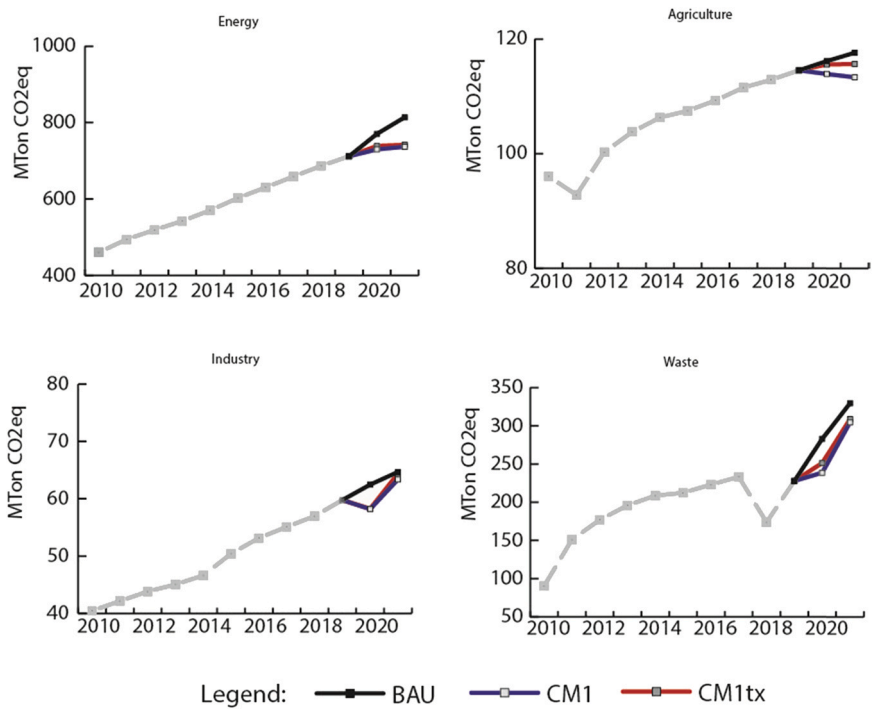

Fig. 7. Sectoral GHG emission under each scenario *Notes: [1] The emissions from land-based sectors are summarised in 'agriculture' (food crops, plantations, woods, livestock, and forest). [2] The emissions from agriculture only counting the emissions from agricultural activity (not include emissions from land use change).*

limited statistical information related to the impact of this pandemic on both the environment and the economy. Therefore, some sensitivity analysis treatment is required.

Here, we tried to compare the pandemic's impact on GDP loss by comparing several different economic growth projections. The economic growth in this CGE model was used to project the capital accumulation owned by Indonesia. Our simulation used the economic growth assumption projected in ADB Economic Outlook published by the ADB (Asian Development Bank, 2020a; Sawada, 2020). The ADB itself revised their projection several times. One of its revisions is stated in ADB Outlook 2020 Supplement (Asian Development Bank, 2020b). In addition to economic projections from ADB, there are several economic projections issued by other agencies such as the IMF and Indonesia National Development Planning Agency (*Badan* Perencanaan *Pembangunan Nasional/ Bappenas*), the latter of which has three growth scenarios: high, medium and low projection.

Different growth scenarios will yield different results. This is because we assume that there is a linear relationship between economic growth and capital accumulation. With the higher economic growth, a country may accumulate more capital, which will lead to more endurance in facing the shock during and post-pandemic. As already mentioned in the methods section, the scenario treatment used in this sensitivity analysis is the same by comparing two results of two scenarios: without fiscal incentives (CM1) and fiscal incentives (CM1Tx) and comparing the outcome to the BAU level. The summary of the economic growth assumption and its effect on GDP loss compared to the BAU level is presented in Table 2.

Our model projects that without subsidies, the GDP loss compared to the BAU level ranges from 4.19% to 6.18% in 2020 and 5.88–9.39% in 2021. The value will depend on the economic growth assumptions. However, on average, the GDP loss will be approximately 5.31% in 2020 and 7.74% in 2021 compared to the BAU level. The economy will improve more significantly with the introduction of a subsidy policy than without any policy. The best projection insight is gained when we use the economic growth scheme BPNHI, which is the most optimist economic projection. In contrast, the lowest projection insight was gained from BPNLO economic growth scheme. However, on average, the subsidies can help improve the economic condition by 1.43% in 2020 and 1.52% in 2021. Although the improvement does not seem major, it will be very meaningful in supporting the economy, especially if the global economy does not recover by 2021. If the global economy improves by 2021, the national economic improvement will be higher. This result also informs us that besides the national policy, Indonesia's economic recovery will also depend on how the global economy improves and the extent to which Indonesia can accumulate capital during the pandemic.

5. Policy implication

This research has several policy implications that the Indonesian government can consider. The most obvious result from our simulation is that the tourism and transportation sectors were hit hardest by the pandemic. Additionally, even with the government's fiscal injection, it is still very challenging for these sectors to return to normal. Thus, the government needs to

Table 2
Comparisons of the results of different GDP growth scenarios.

Economic Growth Scheme	Years	GDP growth	GDP loss (compared to BAU)		Difference (with- without subsidies)
			without subsidies (CM1)	*with subsidies (CM1Tx)*	
ADB (default)[a]	2020	2.50%	-4.19%	-2.76%	1.43%
	2021	5.00%	-7.77%	-6.18%	1.58%
ADB	2020	-1.00%	-6.70%	-5.27%	1.43%
Supplement[b]	2021	5.30%	-9.13%	-6.10%	3.02%
IMF	2020	0.50%	-6.05%	-4.47%	1.58%
	2021	8.20%	-5.88%	-4.81%	1.06%
BPNHI[c]	2020	2.30%	-4.39%	-2.95%	1.44%
	2021	5.50%	-7.35%	-3.99%	3.36%
BPNME[d]	2020	0.30%	-5.73%	-4.36%	1.38%
	2021	5.30%	-8.30%	-7.51%	0.79%
BPNLO[e]	2020	-0.40%	-6.18%	-4.82%	1.35%
	2021	4.50%	-9.39%	-8.58%	0.81%
Average	2020	1.04%	-5.31%	-3.87%	1.43%
	2021	5.70%	-7.74%	-6.21%	1.52%

[a] The simulation in the main script is using this economic growth assumption.
[b] ADB outlook supplement (version June 2020).
[c] Bappenas – High (optimist) economic projection.
[d] Bappenas – Medium economic projection.
[e] Bappenas – Low (pessimist) economic projection.

allocate labour from these sectors to another sector. From this study, agriculture, construction, industry, and other sectors (e.g., service sectors, including the telecommunication sector) are potential sectors to absorb the labour from tourism and transportation sectors, at least for the short term until the situation gets better.

One interesting result is regarding the agricultural sector's role in supporting Indonesia during the pandemic, especially from the food crops and horticulture sub-sectors. It is an interesting and important finding because agricultural sectors always support the national economy during crises, including the previous economic crises in 1998 and 2008 (Andri, 2019). This finding implies that the Indonesian government needs to pay attention to the agricultural sector, especially because many people in rural areas still rely on this sector. Additionally, when there is a crisis, many Indonesian labourers, especially low-skilled labourers, will shift to the agricultural sector (Suryahadi et al., 2012). It is recommended that the government keep improving the management for this sector and realise a strong agro-industry system for it to make a more sustainable contribution to the economy.

Moreover, Indonesia is also dealing with several concerns in realising economic and environmental sustainability. One key to realising it is managing the change in land use, as it is the sector that emits the most emissions. Our simulation shows there is most likely a potential 'land swap', depending on the demand for agricultural products in the market (e.g., land for livestock used to plant food crops when the demand for livestock product drops). By this mechanism, the available mineral land can be sufficient to afford the demand in the market. However, this result is still under the assumption that the farmer can apply that mechanism. All farmers need to have enough information about the market to know which crops/commodities can give them more profit. Additionally, it is recommended for the stakeholders to train the farmers about crops and commodities diversification. It is in line with the study by Nurrochmat et al. (2020) that this kind of a land-swap scenario may be successfully implemented with the presence of incentives to participate, appropriate policies and a facilitative government.

Moreover, Indonesia's industrial sectors have also been negatively affected by the pandemic. However, the shock is as severe as that of the tourism and transportation sectors because some industrial sectors like the food and beverage industries and the chemical and medical industries are still growing (Fauzan, 2020). Considering the uncertainty of the economic situation during the pandemic, the government could do a map of which industrial sub-sectors have performed the best during the pandemic. These sectors have the opportunity to boost economic growth and could even compensate for weaknesses in the other main sectors in the economy, at least during the pandemic.

From an emissions perspective, emissions were estimated to be reduced during the pandemic. However, this reduction was positive, as the emission reduction level was lower compared to the GDP loss during the pandemic. Another area that needs special attention is the fact that the emission growth from the industrial and waste sector was estimated to be even higher under the pandemic. Therefore, it is feared that there will be a significant spike in emissions when the pandemic is over, and the economy recovers. If this happens, it will make it increasingly difficult for Indonesia to achieve its emission reduction targets in both the medium and long term.

6. Conclusion

The pandemic has had a significant impact on the global economy, including on Indonesia's economy. By using a CGE model, we projected that Indonesia's economy would stagnate until 2021. Because of a significant decrease in demand and some

negative shocks on the supply side (including labour layoffs in some sectors), Indonesia will be experiencing a GDP loss of approximately 4.19% in 2020 and 7.77% in 2021, compared to the BAU level. The situation will improve if the government provides some fiscal incentives; then, the GDP loss can be minimised by around 1.43–1.58%. The model also shows that transportation and tourism are two sectors impacted the most by this global pandemic.

Unemployment, especially in the transportation, tourism, and trade sectors, will be temporarily absorbed by the agricultural sectors. This model estimates that when there is a contraction in the industrial and the service sectors, there will be a 'labour pull' in the agricultural sector. However, once the economy starts to recover and the government attempts to accelerate economic development, agricultural labour will gradually decrease, and labour will return to the services and industries sector.

As the government needs to ensure that food stocks last and agricultural labour will increase during the pandemic, land demand will increase, especially for food crops. However, because there is a decrease in demand for livestock products and plantation products in the market, the farmers can convert their land for food crops in the short term. In this manner, the area of forestland can still be maintained during the pandemic. Moreover, we advise the government not to carry out large-scale land conversion to meet food needs during the pandemic. By optimally using a land diversification strategy, Indonesia can still ensure that national food stocks last until 2021.

Along with economic stagnation, the emission levels will also be decreased. Approximately 6–8% of emissions will be reduced during the pandemic, leading to better environmental quality. Emissions will gradually increase when the economic activity recovers and gets closer to the BAU level. Although the pandemic has already improved the emission level, it is unsustainable as the environmental improvement results from economic contraction.

Additionally, there is very limited statistical information to provide a better and more precise simulation. However, our simulation indicates that GDP loss will depend on the country's ability to maintain and retain its capital accumulation. For a small open economy country like Indonesia, the global economic condition will significantly affect national policy and economic growth. Although the government could support the domestic economy through some fiscal intervention, we will still expect economic stagnation if the global economy does not fully recover soon. The Indonesian economy relies on domestic demand and global demand. With the results of this simulation, it is hoped that the Indonesian government can increase its awareness of the global economy and pay special attention to potential sectors that are likely to help its economy during a pandemic.

Acknowledgements

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Appendix 1. Simulation process in CGE [Indonesia]

The model consists of several nested blocks and equations, but in general it consists of production (supply), international and final-demand (utility) trade blocks. The total supply and demand in the model are always assumed to achieve the equilibrium condition through the price mechanism. The condition can be written as:

$\sum_j V(j,i) = \sum_j X(i,j) + C(i) = S(i)$

V (j, i): Production goods i in sector j.

X (i, j):Intermediate demand for goods in sector j.

C (i):Final consumption of goods i.

S (i):Total supply of goods i.

Production block

The first block is the production block. This block consists of a set of production factors including capital and labour that are aggregated as value added. The land is also considered an input, so it is included in the *Production Block* in the model. The production in each sector is disaggregated into subsectors, using the existing new capital stock. Each subsector has a nested production function:

$Max \quad PQ \cdot Q - PVAE(j) \cdot VAE(j) \cdot PLND \cdot LND - \sum_{GHG} PGHG \cdot GHGJA - PS(ne) \cdot X(ne,j)$

$V(j,i) = Q(j) \cdot v_0(j,i)$

$Q \quad (j) = VAE(j) + \quad \sum_{ne} (X(ne,j)) + PLND \cdot LND(j) + \quad \sum_{ghg} GHGJA(j, \quad ghg)).$

Q (j):Activity level of sector j/composite production in sector j.

V (j, i):Production goods i in sector j.

VAE (j):Value added including energy in sector j.

X (ne, j):Intermediate input of non-energy goods (ne) in sector j.

LND (j)Land input in sector j.

GHGJA (j, GHG): GHG emissions from activity in sector j.

v_0:Output coefficient of goods i in sector j.

PLND:Price of land.

PGHG:Price of GHG.

PS (ne):Price of supplied goods (non-energy).
PQ (j):Price of composite production in sector j.

Final demand sector (household and government)

Households hold a very important role in the CGE modelling because they a provider of production factors (e.g. capital, labour, land, etc.). The income for this model can be mathematically summarised as:

$MH = \sum_j P_K \cdot K(j) + P_L \cdot L(j) + P_{LND} \cdot LND \quad (j) + fs + (\quad \sum_i -sc(i)) + \quad g\_h$

MH:Household income K (j):Quantity of capital input L (j):Quantity of labour input LND (j):Land fs:Foreign saving sc (i):Stock change g_h:Transfer between household and government.

The income that is gained from providing these factors is used for consumption. In this model, household has a relation to utility maximization. The parameter connection for the household sector in this model can be described as follows:

$$U = a_U \cdot NEH^{S_{NEH}} \cdot ENEH^{S_{ENEH}}$$

U:Utility of final demand sector.
NEH:Total non-energy demand in household.
ENEH:Total energy demand in household.
s_{NEH}, s_{ENEH}: Share parameter of total non-energy and energy to total utility in household.
a_U:Adjustment parameter for U in household.

Moreover, the government has a function to distribute the welfare. Government income mostly comes from tax income:

$MG = (\sum_i (tx_{o(j)} - tx_m(i)) + \quad (\sum_j (tx_{k(j)} - tx_l(j)) - g_h$

MG:Government Income g_h:Transfer between household and government tx_o (i):Output tax rate tx_k (j):Capital tax rate tx_l (j):Labour tax rate tx_m (i):Import tax rate.

In addition, using that income for consumption can be written as:

$G = \quad TCG + TIG$

G:Total demand in government.
TCG:Total final consumption by government.
TIG:Total investment in government.

International trade block

It is important to introduce the international trade block to the model because we are assuming a small-open economy. The domestically produced goods are allocated for domestic use and exportation, while the domestically supplied goods are coming from imported goods and the goods that are allocated for domestic use. That can be written as:

$$O(i) = a_{ex(i)} \cdot (s\_ex(i) \cdot EX(i)^{al_{ex(i)}} + s\_xd(i) \cdot D(i)^{al_{ex(i)}})^{\frac{1}{al_{ex(i)}}}$$

O (i):Produced goods i.
EX (i):Export of goods i.
D (i):Domestically produced goods i.
PO (i):Price of produced goods i.
PEX (i):Price of exported goods i.
$a_{ex(i)}$:Adjustment parameter for export.
$s_{ex(i)}$:Share parameter of export.
$s_{xd(i)}$:Share parameter of export-domestic goods.
$al_{ex(i)}$:Elasticity of substitution of export-domestic goods.
And:

$$S(i) = a_{im(i)} \cdot (s\_md(i) \cdot D(i)^{-al_{im(i)}} + s\_im(i) \cdot IM(i)^{-al_{im(i)}})^{-\frac{1}{al_{im(i)}}}$$

S (i):Total supply of goods i.
D (i):Domestically produced goods i.
IM (i):Imported goods i.
PS (i):Price of supplied goods (i).
PD (i):Price of domestically produced goods (i) PIM (i):Price of imported goods (i).
$al_{im(i)}$:Substitution parameter between import and domestic use.
$s_{im(i)}$:Share of import.
$s_{md(i)}$:Share of domestic use.
$a_{im(i)}$:Adjustment of import and domestic use.

Moreover, the model is a recursive dynamic model that makes a sequential simulation for each year until reaching the target year (in this study, the target year is 2021). In each year, the capital stock is updated using investment (fixed-capital formation) and depreciation. In general, the process is described below (Fig. A1). This updated investment can come from more advanced

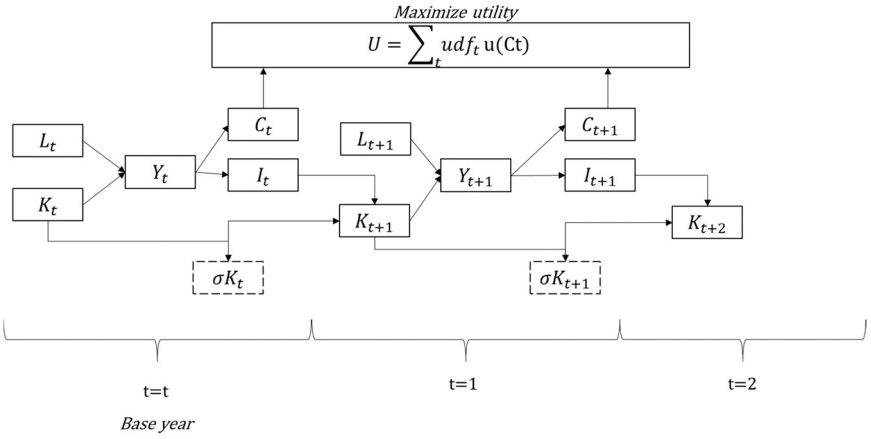

Fig. A1. Illustration of the recursive dynamic process in calculating the capital stock and maximizing the utility. *Notes: U: Social Utility; C: Final Consumption; I: Investment (saving); K: Capital stock; Y: Production; L: Labour; udf: Utility discount factor; δ: Depreciation rate; f(·): Production function; u(·): Utility function.* Source: (Malahayati and Masui, 2021).

or more efficient technology. Also, the capital accumulation is calculated by considering depreciation and economic growth (Fig. A1).

Appendix 2. Indonesia-input table

As mentioned in the main text, the main data used for this study is the input-output (IO) table Indonesia 2010. The IO table is a statistical table that records the flow of all goods and services, including the intermediate transactions between each industry.

Table 2A
The structure and sector connection in Indonesia Input-Output Table.

Sector	Product (q)			Total Intermediate Demand (a)	Final Demand			Total Final Demand (b)	Total output (a+b)
	e.g: Paddy	...	q_n		Consumption	Fixed-Capital Formation	....		
(e.g) Paddy									
...									
qn									
Tax/ subsidy	Tax-Subsidy on product								
Value added	Value added (capital and wage)								
Total Input (a + tax/subsidy + value added)									

Notes: In IO table Total Input = Total Output, that representing total supply = total demand.

In general, it shows the structure of total demand and supply. In the Indonesia IO table, the column shows a sector's intermediate and primary inputs in its production process. The row shows how the output of a sector is allocated to meet intermediate and final demands (Table 2A).

Table 2B
Sector Classification inside the Model.

Indonesia IO-Table classification	*No.*	*Sector Aggregation in the Model*	*Sectoral GDP Group*	*Notes*
Paddy	1	Paddy	food crops	Agricultural Sectors
Corn	2	Corn	food crops	(demand land as input)
Cassava	3	cassava	food crops	
Sweet potato	4	other food crops	food crops	
Other root vegetables				
Peanuts				
Soybean				
Other nuts				
Grain and other food ingredients				
Vegetables				
Fruits				
Medicinal plants				
Rubber	5	Rubber	commercial plantation and wood	
Palm oil	6	Palm oil	commercial plantation and wood	
Decorative plants	7	other plantation	commercial plantation and wood	
Cane				
Tobacco				
plant fibre				
Other Crops				
Coconut				
Coffee				
Tea				
Cocoa				
Clove				
Cashew				
Livestock and Outcomes except Fresh Milk	8	Livestock	livestock and fish	
Fresh milk				
Poultry and Outcomes				
Results Maintenance Other Animals				
wood	9	Wood	commercial plantation and wood	
Other Forest Products	10	Other forest	forest	
Fish	11	Marine and fishery	mining	
Shrimp and other crustaceans				
Other aquatic biota				
Seaweed and the like				
Coal and lignite	12	Coal mining	mining	
Crude oil	13	Crude oil mining	mining	
Natural Gas and Geothermal	14	Natural gas mining	mining	
Iron sand and iron ore	15	Other mining	mining	
Tin ore				
Bauxite ore				
Copper ore				
Nickel ore				
Other Metals Mining Goods				
Gold ore				
Silver ore				
Excavation goods Any Type				
Non Metallic Mineral Mining Goods				
Coarse salt				
Services Petroleum and natural gas				
Services Other mining and quarrying				

(*continued on next page*)

Table 2B (*continued*)

Indonesia IO-Table classification	*No.*	*Sector Aggregation in the Model*	*Sectoral GDP Group*	*Notes*
Results Abattoirs	16	Food, beverage, and tobacco	industries	
Results Processing And Preserving Meats				
Dried Fish and Salted Fish				
Results Processing and Preserving Fish				
Results Processing and Preservation of Fruits and Vegetables				
Oil Animal and Vegetable Oils				
Copra				
Food and Drink Made of Milk				
Other flour				
Wheat flour and meslin flour				
And the results of Rice Milling Rice milling				
Bread, biscuits and the like				
Sugar				
Chocolate and Candy				
Noodles, Macaroni and the like				
Processed coffee				
Processed tea				
Processed soy				
Other Food				
Processed Pet Food				
Alcoholic beverages				
No Alcoholic Beverages				
cigarette				
Processed tobacco				
Yarn	17	Textile, foot and leather	industries	
textiles				
Tapestries, Ropes & Other Floor Coverings				
In addition to items of Textile Fabrics and Garments				
Knitted goods				
Apparel				
Results Preservation And Tannery				
Goods from Leather				
Footwear				
Sawn Timber and Processed	18	Processed wood products	industries	
Plywood and Allied				
Building Materials From Wood				
Other goods of wood, cork, Bamboo and Rattan				
Paper pulp	19	Pulp and Paper Products, and print	industries	
Paper				
Goods Of Paper And Cardboard				
Printed goods				
Results of Oil and Gas Refineries	20	Petroleum refineries	industries	
Basic Chemicals Except Fertilizers	21	Chemical industry	industries	
Paints and printing inks				
Varnishes And Lak				
Soap and cleaning agents				
Cosmetics				
Other chemical goods				
pharmaceutical products				
Traditional medicine				
Fertilizer	22	fertiliser and pesticide	industries	
Pesticide			industries	
Other non-metal products	23	non-metal industries	industries	
Synthetic resins, Plastics Material and Synthetic Fibers				
Tire				
Crumb Rubber and Rubber Smoke				
Other items of Rubber				
Goods of Plastics				
Glass and goods from glass				
Goods of clay, ceramic and porcelain				
Cement	24	Cement	industries	
Iron and steel	25	Iron and steel	industries	

(*continued on next page*)

Table 2B (*continued*)

Indonesia IO-Table classification	*No.*	*Sector Aggregation in the Model*	*Sectoral GDP Group*	*Notes*
metal non- iron	26	Metal and non-metal product	industries	
Goods of metal casting				
Metal Building Materials				
Weapons and ammunition, metallurgy and metal goods manufacturing services				
Kitchen tools, carpentry, metal household furniture				
Other metal goods				
Electronic goods, Communications and Fittings	27	Other industries	industries	
Measurement, Photography, Optics and Clocks				
Plant Engineering And Electric Motors				
Electrical Engineering And Fittings				
Battery And Battery				
Other Electrical Equipment				
For Household Electric Appliances				
Machinery Movers Mula				
Machines for office and accounting purposes, and parts and equipment				
Other machinery and equipment				
Except Motor Vehicles Motorcycles				
Boats And Services Improvement				
Train And Services Improvement				
Aircraft And Services Improvement				
Other Transportation Equipment				
Motorcycle				
Household furnishings and office addition of Metal				
Jewelry				
Musical instruments				
Tools Sports				
Tools Games and toys children				
Medical Equipment				
Goods of other processing industries				
Service and repair of metal products manufacturers, machinery and equipment				
electricity	28	Electricity	utilities	
The results of natural and artificial gas, supplying steam / hot water, cold air and ice products	29	Gas (Town gas)	utilities	
Water Supply	30	Water supply	utilities	
Waste Management, Waste and Recycling	31	Waste and recycling services	other services	
Residential Building and Not Dwelling	32	Construction	construction	
Building & Installation Electrical, Gas, Water And Communications				
Agricultural infrastructure				
Roads, Bridges and Ports				
Real Estate Services				
Other buildings				
Rail Transport Services	33	Transportation	transportation	
Land Transport Services Besides Rail Transport				
Sea Transport Services				
River Transport Services Lake Crossing				
Air Transport Services				
Transportation Support Services				
Wholesale trade of car and motor vehicles	34	Trade	trade	
Trading besides Cars and Motorcycles			tourism	
Eating and Drinking Services	35	Tourism	other services	
Accommodation Services			other services	
Broadcasting services and programming, Film and Sound Recording Results	36	telecommunication services	other services	
Telecommunications services				
Consulting Services of computer and information technology				
Postal and Courier Services				
Financial Services Banking	37	Financial Services	other services	
insurance services				
Pension Fund Services				
Services Other Financial Institutions				
General Government Services	38	Government Public Administration	other services	
Government Educational Services				
Government Health Services				
Other Government Services				

(*continued on next page*)

Table 2B (*continued*)

Indonesia IO-Table classification	*No.*	*Sector Aggregation in the Model*	*Sectoral GDP Group*	*Notes*
Private Education Services Health & Social Services Private Event Professional, Scientific and Technical	39	services provided by private	other services	
Services Agriculture, Forestry and Fisheries Repair and Maintenance Cars and Motorcycles Advertising services Services Leasing and Business Support Services Services Arts, Entertainment and Recreation Personal Household Goods Repair and More Other services	40	Other services	other services	

In Indonesia IO Table 2010, there are 185 sectors (q_1,….,q_{185}), the detail of each sector classification can also be found and accessed in Badan Pusat Statistik (2015) (the reference can be found in the reference list). For this study, we did the sector reclassification through the aggregation of the sector. The sector classification for this study is as it is in Table 2B.

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