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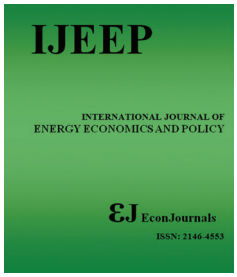

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Economic Effect of Biodiesel Downstream Industry: An Analysis Based on a Dynamic CGE Model

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ABSTRACT

The palm oil commodity is a key export and a major source of foreign exchange for Indonesia. Additionally, processed palm oil plays a crucial role as a domestic source of food (cooking oil) and renewable energy (biodiesel). The biodiesel industry, which processes Crude Palm Oil (CPO) derivatives into biofuel, holds significant potential for development to meet both domestic consumption and export demands. However, the diversification of CPO products and biodiesel downstream production impacts the availability of domestic cooking oil and CPO export supplies, with Indonesia being the largest exporter globally. The downstream industry, including agro-based industries like biodiesel, is a strategic policy outlined by the government as a primary driver of national economic growth. This research aims to analyze the economic impact of downstreaming in CPO-based biodiesel. The primary data used is the 2016 Indonesia Input-Output Table, updated to 2023. The model is based on a Dynamic CGE Model of Orani-F and the Wayang model. The result shows that biodiesel downstream policy will stimulate economy growth, investment, and national export in the long run. Following biodiesel upstream policy is needed in order to support the development of energy security and food security simultaneously.

Keywords: Downstreaming, Biodiesel, Oil Palm, Industrialization, Export
JEL Classifications: Q01, Q42, O13

1. INTRODUCTION

Indonesia is the largest producer of Crude Palm Oil (CPO) in the world, making palm oil a leading sector in generating foreign exchange from exports, providing employment opportunities, and serving as a source of household income. In 2021, Indonesia contributed approximately 58%, equivalent to 46.5 million tons, to the global palm oil supply (Ministry of Agriculture Directorate General of Plantations, 2024). CPO exports contribute an average of more than 4 percent to Indonesia's Gross Domestic Product (GDP) annually.

The downstream development of the palm oil industry has been ongoing for some time, following the release of the palm oil downstream industry development roadmap, regulated through Minister of Industry Regulation No. 13 of 2010 concerning Amendments to Minister of Industry Regulation No. 111/M-IND/PER/10/2009 on the Development Guidelines for the Palm Oil Downstream Industry Cluster. Palm oil derivatives play a crucial role as sources of food (cooking oil), non-food products, and renewable energy (biodiesel). However, because approximately 60% of national CPO production is exported, the added value from the downstream palm oil industry is not fully enjoyed domestically. Its role as a renewable energy source will eventually lead to the restructuring of fuel subsidies (Yen et al., 2023). In many countries, policies prioritizing renewable energy have also become a top choice (Farouq and Sulong (2024); Azzahrah et al., (2023)).

One of the palm oil industries with great potential for growth in the global market is biodiesel. The biodiesel industry, which processes CPO derivatives into biofuel, holds significant potential for development to meet both domestic consumption and export demand (Devita, 2015). In 2022, the composition of raw material exports included 2% CPO and 4% Crude Palm Kernel Oil (CPKO), while processed product exports consisted of 73% refinery products (initial processing of CPO to produce RBDPO — Refined Bleached Deodorized Palm Oil) and 21% other products (Indonesia.go.id, 2024).

British Petroleum reported that global biofuel production reached 1.68 million barrels of oil equivalent per day (bopd) in 2020 (Databoks, 2021). Indonesia ranked third with a biofuel production of 126 thousand bopd. With the implementation of the B30 Mandatory Program, all diesel fuel in Indonesia is required to contain at least 30% biodiesel and 70% fossil diesel. In 2022, the government increased the biodiesel content to B40. This development opens up even greater potential for downstream biofuel processing, particularly biodiesel. During 2024 the government had been carried out B40 application test for non automotives such as train, heavy equipment, ships, agricultural tools and machinery. Implementation of B40 program will be started in 2025 (Ministry of Energy and Mineral Resources, 2024a).

However, the diversification of CPO products and the downstream development of biodiesel have impacted the domestic availability of cooking oil and the export supply of CPO. The government's policy of directing Indonesia's CPO towards biofuel (or called as Bahan Bakar Nabati (BBN) or fuels derived from plants, animals and plantation and livestock waste other than fossils) presents the potential for disruptions between the domestic consumption needs of CPO and the development of the downstream biofuel industry (Ministry of Industry, 2024a). The increase in Indonesia's CPO production has been accompanied by a positive trend in CPO consumption, both domestically and internationally. However, due to the substitution of CPO for renewable energy, less than half of the growth in palm oil consumption will be realized (Gaskell, 2015).

The high demand for biofuels as fuel has led to a shortage of vegetable oils as a food source. This situation has intensified the debate between food versus fuel. The development of biodiesel downstream industries has encouraged upstream palm oil companies to explore entering the biofuel business (Industri Kontan, 2024). Biofuels (BBN) are often viewed with skepticism, as they are believed to increase risks to food security. There is a concern that the growing use of land for non-food crops, such as for biofuels, will simultaneously reduce the production of food crops (PT Sinar Mas Agro Resources and Technology Tbk (PT SMART Tbk), 2024). This is feared to trigger rising food prices and exacerbate food security risks.

The government's planning to regulate the availability of biodiesel domestically is crucial to maintaining price stability and ensuring a consistent energy supply. This research is significant as a reference for the government to assess the impact of biodiesel usage choices, whether for energy or food, and how these choices affect the national economy and CPO exports. Figure 1 illustrates the growth of biodiesel production in Indonesia, highlighting the country's increasing commitment to biofuel development.

The downstream development of biodiesel will inevitably impact the industrialization of palm oil and its exports. Several countries have analyzed the economic and export impacts of biodiesel growth. For instance, Croatia experienced positive effects (Kulišić et al., 2007), Argentina faced a decline in output and welfare (Timilsina, 2013), and Brazil saw positive effects on its economy (De Oliveira and Coelho, 2017).

Based on these issues, this study aims to analyze the impact of downstreaming in biodiesel from CPO on Indonesia's economy, particularly regarding macro and industries performs. The urgency of this research is to understand and address the food versus fuel availability dilemma, as well as to predict how the downstream development of the biodiesel industry will affect industrialization in the palm oil sector and the export of Indonesia's CPO derivative products. By identifying the impacts, policymakers can anticipate potential shortages in CPO derivative products for both food and energy, as well as ensure foreign exchange earnings through exports. To better illustrate the productivity trends in the palm oil sector, Figure 2 below shows the current state of palm oil productivity in Indonesia, highlighting its significant role in both food and energy production.

Additionally, this research is relevant to the Sustainable Development Goals (SDGs), particularly SDGs 7 and 8, which focus on affordable and clean energy, and decent work and economic growth. Anticipating energy scarcity and affordability by understanding the impacts of government policies will ensure the achievement of clean and affordable energy. Furthermore, downstream development in the biodiesel sector is expected to increase exports, create more employment opportunities, and boost national economic activity. In turn, SDGs 8, decent work and economic growth, will be achieved.

The approach and problem-solving strategy used in this research involves modeling and conducting impact analysis calculations on the Indonesian economy. By simulating biodiesel downstream policy, the study aims to observe its effects on the economy, particularly on industrialization in other palm oil derivative sectors and Indonesia's CPO exports.

2. LITERATURE REVIEW

2.1. Downstreaming of Indonesia's palm oil

Coconut and palm oil are Indonesian commodities with significant potential. Indonesia ranks first as a producer of coconut oil and is one of the largest palm oil producers globally, second only to Malaysia. As the world's second-largest producer after Malaysia, Indonesia holds considerable potential to develop its downstream industries beyond cooking oil. Indonesia has predominantly exported crude palm oil (CPO), resulting in relatively low value-added benefits.

Indonesia's CPO export trade ranks among the top five largest commodities, competing with products from the mining sector. The product, classified under Harmonized Systems (HS) code 1511.10.00, is exported to various countries, including India, the Netherlands, Singapore, Italy, and others. Indonesia is the world's largest CPO producer, commanding a 32.64% market share (Hafizah, 2011), and contributes 52.65% to the world's CPO supply (Hudori, 2016; Pknstan, 2024).

Ministry of Industry (2012) introduced the industrial downstream program as a strategic step to increase the added value of raw material products in Indonesia, encourage more sustainable economic growth and increase the contribution of the industrial sector to Gross Domestic Product (GDP). The program started in 2010 with the aim of strengthening the national industrial structure, creating jobs, and providing business opportunities for the community (The Ministry of Industry, 2012). In their article, "Increased Investment and Nickel Downstreaming in Indonesia" (Agung and Adi, 2022), the authors elucidate the ongoing phenomenon of downstreaming in natural resource in Indonesia. They elucidate that downstreaming, particularly in the nickel sector, is intended to augment domestic value-added and curtail raw material exports. Downstreaming is a policy that encourages the optimal utilization of natural resources within the country, with the objective of transforming exported products from raw materials into semi-finished goods or final products that possess a higher economic value. From a macroeconomic perspective, downstreaming is thought to enhance the industrial sector's contribution to a country's gross domestic product (GDP), given that products at the later stages of the industrial chain tend to possess higher economic value. This indicates that the further a product is processed, the greater the added value that can be generated. Consequently, downstreaming represents a pivotal strategy for enhancing the competitiveness of domestic products in the global market and plays a crucial role in Indonesia's sustainable economic development (Agung and Adi, 2022, Pakpahan and Puspitawati, 2022).

An article by Berlian (2015) discussed the downstream strategy of Indonesia's palm oil industry. Downstreaming allowed palm oil products to be processed into intermediate goods by downstream industries, such as oleo-food products (margarine and cooking oil) and oleochemicals (fatty acids and fatty alcohols). The final products were produced by downstream industries engaged in sectors such as fuel (biodiesel), food processing, cosmetics, pharmaceuticals, and metal manufacturing. This increased added value and advanced the domestic economy (Berlian, 2015).

Hasibuan and Thaheer (2017) emphasize that Indonesia's palm oil production has largely focused on crude palm oil (CPO). To bolster the role of the palm oil sector as a key driver of Indonesia's future economic growth, the government initiated a downstream strategy in 2012. The main aim of this strategy is to increase the added value of palm oil products and reduce the vulnerability to global price fluctuations. By moving further downstream in the production process, palm oil products become less susceptible to market volatility, enhancing sustainability and economic resilience for the industry (Hasibuan and Thaheer, 2017).

Biodiesel down streaming is part of Indonesia's efforts to increase the value-added of palm oil products and reduce its dependence on raw material exports, such as crude palm oil (CPO). This down streaming process aligns with the government's strategy to develop the domestic industry, expand the domestic market for biodiesel, and increase exports of processed products with higher value.

Minister of Finance Regulation No. 128/PMK.011/2011 is an important regulation that revises Minister of Finance Regulation No. 67/PMK.011/2010 regarding the imposition of export duties on exported goods. One of the main policies in this regulation is the setting of higher export duty rates for upstream palm oil products, compared to downstream products. This measure aims to encourage the development of the downstream palm oil industry in Indonesia by providing incentives through reduced export duties for downstream products. This regulation is an important momentum that triggers the growth of the domestic palm oil processing industry.

The implementation of downstreaming in palm oil has shown positive changes for Indonesia. In 2011, the composition of CPO exports relative to downstream CPO products was 60:40, whereas by 2013, the composition had shifted to 40:60. Besides this export composition, Indonesia' downstream policy has also positively impacted product diversification. In 2011, Indonesia produced 54 types of downstream CPO products, but by 2014, this number had grown to 169 types. However, the productivity of Indonesia's palm oil downstream industry remains lower than that of Malaysia, which boasts a 20:80 export composition. This demonstrates that Indonesia's palm oil downstream efforts have not yet been optimized (Berlian, 2015).

According to the Asian Development Bank (2018), downstreaming of Indonesia's biodiesel had significantly contributed to increasing the value-added of palm oil products and created new jobs in the processing industry. The increased domestic biodiesel production capacity has also helped reduce Indonesia's reliance on fossil fuel imports, thereby strengthening national energy security and supporting sustainable economic growth.

Several studies have examined the relationship between CPO prices and Indonesian palm oil exports. Azahari (2019) explored the connection between the palm oil downstream industry and palm oil derivatives. The study revealed that Indonesia still has substantial potential to enhance value-added through the processing industry of palm oil derivatives, considering both market demand and supply factors. Despite negative campaigns against palm oil products (CPO) and their derivatives, global palm oil demand continues to rise. On the supply side, the availability of land, labor, and cultivation technology remains highly supportive (Pertanian.go.id, 2024). A literature review by Susanto (2020) highlights the important role of biodiesel in supporting national energy innovation in Indonesia. Biodiesel, produced from crude palm oil (CPO), is an environmentally friendly alternative fuel that aims to replace the use of fossil fuels, particularly diesel. In the context of export competitiveness, downstreaming from CPO into biodiesel increased the added value of the product and helped reduce dependence on fossil fuel imports. It also promoted national

energy sustainability and made an important contribution to a greener and more sustainable energy sector (Gultom et al., 2023).

Gultom et al. (2023) conducted a study analyzing the impact of international prices, exports, fresh fruit bunch (TBS) prices, and biodiesel production volume on domestic CPO prices. The study aimed to evaluate the impact of the biodiesel industry's development on domestic CPO prices, using secondary data from 1997–2021. Multiple linear regression, processed with Ordinary Least Square (OLS), was used for analysis. The study found that international CPO prices, CPO export volume, and TBS prices significantly affected domestic CPO prices, whereas biodiesel production volume did not have significant affected (Indonesian Palm Oil Association (GAPKI), 2022). Based on the study from GAPKI, although Indonesia's palm oil exports were previously dominated by crude palm oil (CPO), deeper downstreaming had successfully reduced CPO export shares to less than 10%, with over 90% of exports, and comprising higher-value processed products. Moreover, the development of the biodiesel industry has contributed to improving Indonesia's energy security and saving USD 8 billion annually through reduced diesel fuel imports (Farobie and Hartulistiyoso, 2021).

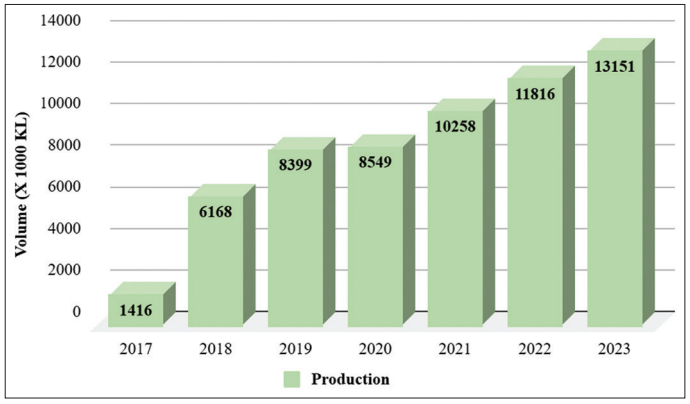
However, challenges remain in meeting international standards and diversifying processed products, which must be addressed to strengthen Indonesia's position as a leading vegetable oil producer in global markets. Furthermore, a research by Dey et al. (2021) found that Indonesia's palm oil-based biodiesel program positively impacted to national energy security, reduced fossil fuel imports, and saved USD 8 billion per year (Wang, 2022).

In his research, Wang (2022) highlighted the central role of the state in developing Indonesia's palm oil-based biofuel production network. Through various resource nationalism policies, the government sought to promote downstreaming in palm oil to increase value-added and reduce dependence on raw material exports. The study underscored the importance of developing Indonesia's palm oil downstream industry, with the state playing a significant role in the entire biofuel production network to upgrade the palm oil industry and achieve higher value. By mastering more complex production processes, the country was expected to gain better control over CPO prices in international markets and strengthen its bargaining position in negotiations with other countries (Soemanto et al., 2023).

In their research, Soemanto et al. (2023) emphasized the crucial role of biofuels in supporting Indonesia's energy transition. The researchers concluded that government policies promoting biodiesel consumption, particularly through subsidy mechanisms based on the biodiesel B100 and biofuel Market Index Price (HIP-BBN), had significantly increased biodiesel usage. The stability of CPO prices had also been a key factor in rising biodiesel consumption. Thus, this study provided empirical evidence of the effectiveness of government policies in driving the energy transition towards net-zero emissions (Kurniawati et al., 2022).

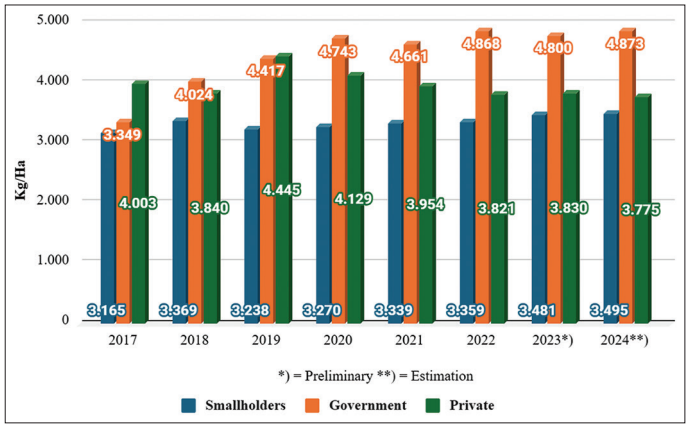
Kurniawati et al. (2022) highlighted the importance of understanding the potential of palm oil-based biodiesel as an alternative energy

Figure 1: Indonesian biodiesel production



Source: APROBI (2024)

Figure 2: Palm oil productivity



Source: Ministry of Agriculture (2023)

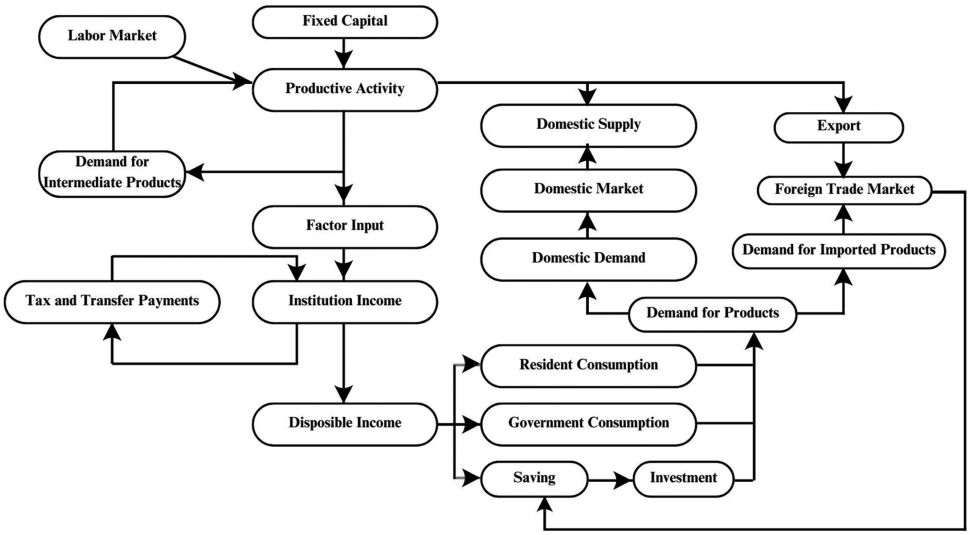
source in Indonesia. The study not only explored the benefits of biodiesel use but also identified several challenges, such as the need to enhance the quality standards of biodiesel to be equivalent to international standards, meet transportation technology needs, and address policy impacts on CPO export opportunities. The findings of this study can serve as a basis for the government and industry to formulate more comprehensive policies and strategies for the future development of the biodiesel industry. Failure to address these issues could open the door for the biodiesel program policy to lead to trade balance deficits (Ebadian et al., 2020).

Research by Ebadian et al. (2020) found that biofuel blending mandates, which require the blending of a certain percentage of biofuel into fuel, are the most effective policy for stimulating biofuel production and usage globally. This policy has proven successful in establishing and growing a stable biofuel market (Kurniawati et al., 2022). With lower prices and abundant supply, downstream CPO industries have taken advantage of the impact of the export duty by increasing domestic CPO consumption to produce high-value-added derivative products (Irawan and Soesilo, 2021).

2.2. The advantages of CGE models in the policy impact analysis

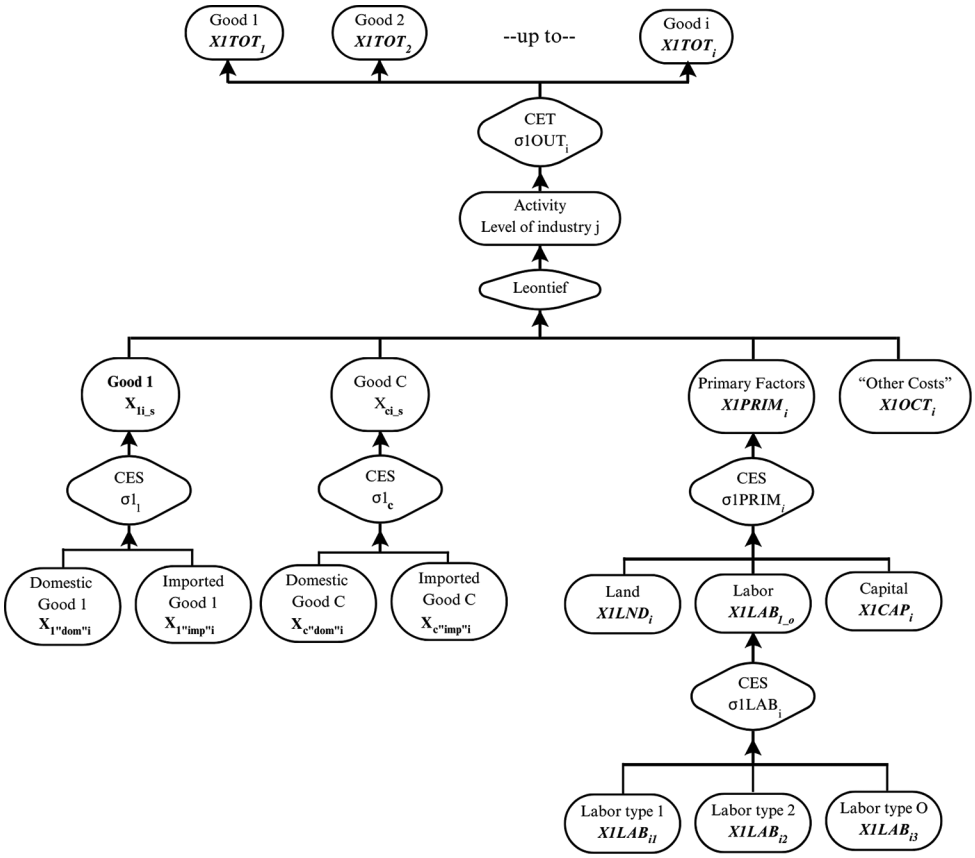
The literature review from Agustina and Hartono (2022) discussed the impact of changes in corporate income tax rates and value-

Figure 3: Structured model of CGE



Source: He et al. (2010)

Figure 4: Production structure of the biodiesel CGE model



added tax in Indonesia with a comprehensive economic analysis approach. This study emphasized impact assessment of a policy on the economy as a whole, and the use of a general equilibrium model which was very effective. This model was able to capture the effects of policies simultaneously on all economic agents, including households, firms, and government. One model that was often used in this context waas the Computable General Equilibrium (CGE) model. CGE models had the advantage of disaggregating households by income level and firms by various business sectors. This capability allowed for an in-depth analysis of the impact of policies on different groups of households and business sectors, provided clearer insights into the economic consequences of the tax rate changes implemented. As such, this research contributed to a better understanding of the interaction between tax policy and the Indonesian economy (Agustina and Hartono, 2022).

Huang et al. (2020) discussed the role of the Computable General Equilibrium (CGE) model in analyzing income disparity and inequality in China in the context of clean energy transformation.

The CGE models provided a comprehensive perspective on the economy by integrating all economic agents, including households, firms, governments, and foreign sectors, within a framework that is compatible with microeconomic theory and empirical data. The growing popularity of this model demonstrated its effectiveness in providing holistic economic analysis. CGE models were often used by researchers to analyze policy impacts and able to reveal the individual impacts of policies on different groups of households and business sectors, thus provided deeper insights into how clean energy policies may affect income inequality in China (Huang et al., 2020).

Kartini and Margaret (2020) explored the impact of tariff policies on the agricultural sector in Indonesia through the analysis of the Global Trade Analysis Project (GTAP) model. This research highlighted the use of a Computable General Equilibrium (CGE) model, which consisted of a series of mathematical equations that represent the entire economy as well as the interactions between economic agents. The advantage of the CGE model analysis over partial equilibrium approaches lay in its ability to provide a comprehensive evaluation of the economy, rather than an isolated analysis of a particular market or sector. With this approach, Kartini and Margaret's study could reveal how tariff policy affects the agricultural sector more broadly, including its impact on interactions with other sectors in the Indonesian economy. The results of the analysis were expected to provide valuable insights for policy makers in formulating more effective and sustainable policies in the agricultural sector (Kartini and Margaret, 2020).

Table 1: List of sector

Full name	Label	Full name	Label
Agriculture, forestry, and fishery	AGR	Biodiesel	BIO
Coal	COAL	Motor vehicles	MV
Oil and gas	OILGAS	Aircraft	AIR
Other mining	OM	Other transportation	OTR
Other manufactures	OMN	Construction	CONST
Cooking oil	COIL	Services	SERV
Oil palm	OPALM		

3. RESEARCH METHOD

3.1. Data

The main data used in this research was Indonesian Table Input-Output 2016 which was updated into 2023 as the base year of the model. Other data included National Socioeconomic Survey (Susenas), National Labor Force Survey (Sakernas), the System of Social National Accounts (SNSE), other elasticity and parameter values. The base year for this model is 2023 and time horizon is 2023-2030, the economy is divided into 13 sectors and they are listed in Table 1.

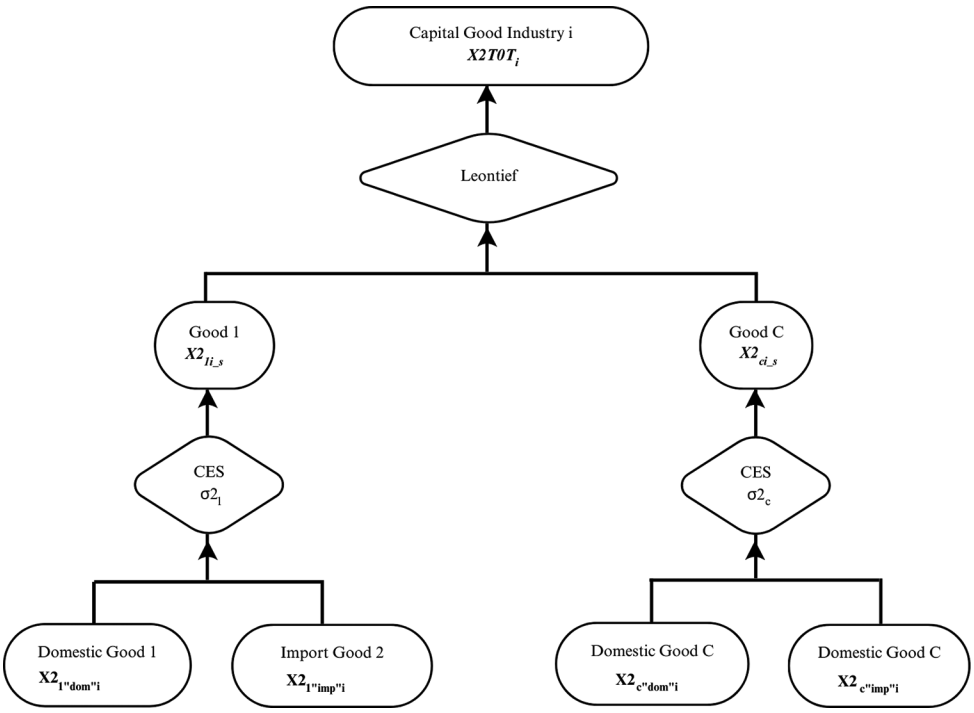
3.2. Methodology

3.2.1. CGE model

The main model used in this research is the Computable General Equilibrium (CGE) Model. In contrast to other economic models which generally can only capture the impact of a policy or shock partially (only looking at the macro or sectoral side), in the general balance model the impact of a policy or shock can be evaluated simultaneously. The basic model used in this research comes from the CGE model based on Orani-F (Horridge, 2006) and the Wayang model (Wittwer, 1999).

The biodiesel CGE model is divided into 18 blocks: demands for labor, demands for primary factors, demands for intermediate inputs, demands for composite primary factors and intermediate inputs, commodity composites of industry outputs), demands for

Figure 5: Structure of investment formation and capital goods in the biodiesel CGE model



investment goods, household demands, export and other final demands, demands for margins, purchaser's prices, market clearing conditions, indirect taxes, GDP from the income and expenditure sides, trade balance and other aggregates, rates of return, indexation, investment-capital accumulation, debt accumulation, and regional extension. The model was developed based on Walras paradigm, meant as described as a system of simultaneous equations deduced by all economic actors' maximizing behavior. The system of equations was modeled and solved by a software named General Equilibrium Modelling PACKage (GEMPACK). The model structure is illustrated as Figure 3.

The CGE model was developed based on Walras paradigm, meant as described as a system of simultaneous equations deduced by all economic actors' maximizing behavior. The model structure can be illustrated as the Figure 5. The system of equations was modeled and solved by a software named General Equilibrium Modelling PACKage (GEMPACK).

3.2.2. Production and investment block

The main blocks related to downstream sectors of biodiesel is on the production and investment structure. Goods represent sectors or industries in the economy. The production process is a multi-stage which is illustrated by Figure 4, characterized by the constant elasticity of substitution (CES) function at the initial level, and the Leontief function and Constant-Elasticity-of-Transformation (CET) at the higher level (Horridge, 2006). While in the investment structure which is adopted from Silva and Horridge (1996), the initial stages show the use of imported and domestic goods which is determined based on cost minimization with the CES production function. The investment structure of the CGE model in this study is shown by Figure 5.

3.2.3. Dynamic model

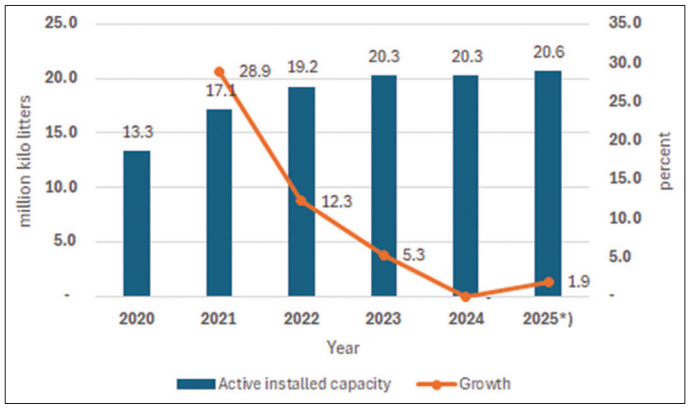
In this study, the CGE models have been adapted to be a dynamic model, which is to add a time dimension to all the variables and parameters and then solve the CGE equation one by one period. The dynamic CGE model refers to period time variant where capital stocks available for use in year t which are formed by investment in year t−1 and before. The dynamic model represents behavior of households and firms being forward-looking and stock accumulation interactions (Nordhaus and Yang, 1996).

3.3. Simulation

We focus on the biodiesel downstream program by Indonesian government in order to achieved accelerated growth and SDGs 7 which is affordable and clean energy. Then the scenario adopted in this research was as a growth of investment which was measured by active installed capacity of the biodiesel production. The data by APROBI showed that active installed capacity by biodiesel companies in Indonesia increased from 13.3 million KL in 2020 to 20.64 million KL as revealed by Figure 6. Since biodiesel mandatory policy in 2020 has been started implementation of B30, the investment increased significantly about 28.9 percent from 2020 to 2021. Until 2024 the biodiesel mandatory has been implemented into B35. It is expected to continue to be B40 in 2025.

We applied a scenario of biodiesel downstream policy in the CGE model. The scenario was constructed from the average growth of

Figure 6: Average growth of active installed capacity as the scenario of biodiesel downstream policy



*Projection data for 2025. Source: APROBI (2024)

Figure 7: Annual growth rates of key macro indicators generated by biodiesel downstream scenario of the biodiesel dynamic CGE model

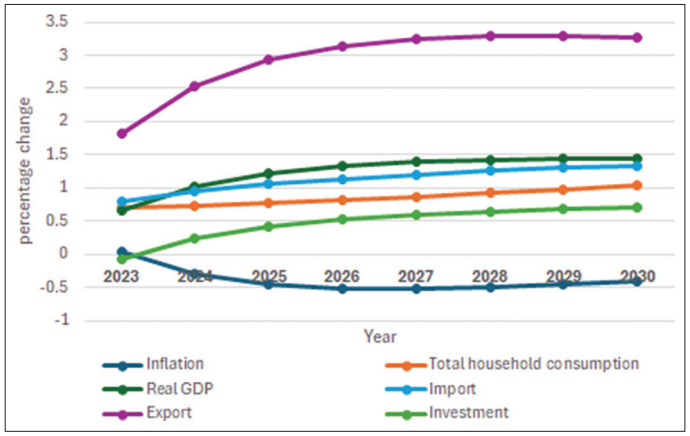
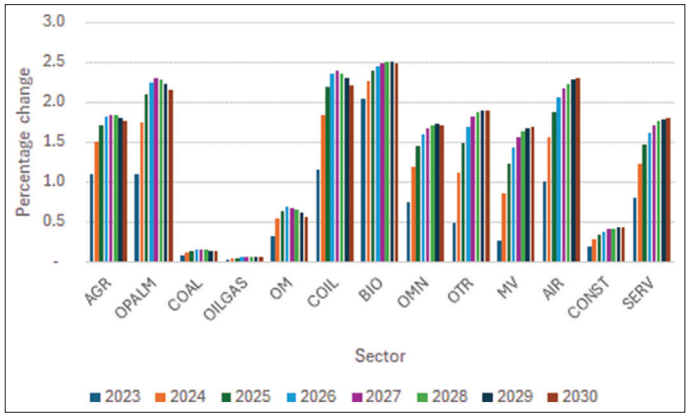


Figure 8: Annual growth rates of industrial output generated by biodiesel downstream scenario of the dynamic biodiesel CGE model



biodiesel active installed capacity, which is 9.66 percent. It was as the shock value of biodiesel investment simulation.

4. DISCUSSION

4.1. Macro economy impact

To examine how Indonesian economy responds to the biodiesel downstream policy, the dynamic CGE results are described by

Figure 7. The result shows that downstream policy especially on biodiesel gives different impacts on macroeconomy performance. The policy will impact on the total household consumption which will increase from 0.7 percent in 2023 to 1.04 in 2030. The increasing of investment though downstream policy will increase production and productivity in the long run. This in turn will influence a decreasing price of goods and services food which is shown by decreasing inflation and then generate higher household expenditure.

In the simulation, the decreasing inflation is pushed by a positive growth of investment in biodiesel and a positive net export. With a better investment of biodiesel industry, inflation will decrease in the long run. As consequence, national real GDP will up from 0.67 percent in 2023 to 1.45 percent in 2030. Export will also increase since the development of downstreaming in biodiesel. The development of biodiesel industry in Indonesia is not only support to boost national economic, but also to secure the national energy security (Pambudi et al., 2019).

However, this study gives a different perspective from a study by Sahara et al. (2022) regarding the impact on inflation. Sahara's study that using shocks of the B30 mandate and the effect of the EU trade ban still yield an inflationary effect in the short term. It did not see the impact of biodiesel mandatory in the long term.

4.2. Industrial Impact

The impacts of biodiesel downstream on sectoral performances can be seen from Figure 8. The shock of the policy will not only cause an increasing output at downstream industry of biodiesel (OPALM) but also at the upstream industry. Biodiesel industry (BIO) itself will grow balancing the downstream biodiesel investment. Oil palm as the upstream industry will be encouraged to supply biodiesel raw materials. A study by Firdaus et al. (2019) shows an upward trend of national energy security level in the biodiesel agroindustry context which indicates the on-track direction of biodiesel agroindustry development in Indonesia. Contribution of Indonesia's renewable energy of 13.09% to the national energy mix, is about 7.7% is contributed by biodiesel (Ministry of Energy and Mineral Resources, 2024b).

Cooking oil (COIL) as a competitor of biodiesel will also increase with a lower growth. Agricultural sector (AGR) will also improve since its subsectors support as inputs. If the biodiesel mandatory will be continued and increased into B100, there must be an implication on the cooking oil stock, since the input of cooking oil and biodiesel is complementary.

However, Ministry of Industry (2024b) reported that during 2022 cooking oil production from CPO has exceeded national needs or over supply. CPO production in 2022 was about 51.54 million ton. Based on Ministry of Trade Decree No. 1528 in 2022, the need of cooking oil in the form of simple packaging or Minyakita for people's consumption is about 3.24 million ton per year. While the use of CPO for cooking (domestic) is forecasted about 10.18 million ton in 2023 and 11.3 million ton in 2030 with a trend growth of 1.5 percent. Ministry of Industry estimates the use of CPO for food (cooking) was about 20.30 percent of total CPO production. The use of CPO for biodiesel, oleochemical, and CPO export is estimated by the government about 21.20, 4.50, and 6.5 percent from 2023 to 2045. Thus, there should no longer be a debate between the interests of national food and energy security.

Alternatively, the use of used cooking oil (UCO) for input of biodiesel can be as an alternative solution of the limited CPO. UCO is a derivative product that can be used as a substitute for diesel oil for diesel engines for the transportation or industrial sectors. A study by Kharina et al. (2018) shows that UCO as a waste product offers a lower cost of biodiesel industry, and ecological benefits of avoiding UCO disposal into the local waterways and landfill as well as health benefits of avoiding UCO reuse in food.

Another result of the model simulation in this study reveals that motor vehicle industry growth should follow the increasing growth of biodiesel industry with a lower growth. It will increase significantly if the biodiesel mandatory will be continued to achieve B100.

5. CONCLUSION

The result of this study indicates the biodiesel downstream policy will affect Indonesia's economy. The policy will stimulate economy growth, investment, and national export in the long run. The development of biodiesel downstream is not only support to raise national economic, but also to secure the national energy security. Thus, downstreaming in biodiesel is needed to be accelerated.

There should be no longer a discourse between the interests of national food and energy security. The use of CPO for food (cooking) is estimated enough to be supplied from the Indonesia's CPO production. However the fluctuated CPO price threatens the sustainability of the biodiesel industry and downstream program. Another alternative to supply the need of biofuel feedstocks is used cooking oil (UCO). UCO is a waste product that can be used as CPO substitution for diesel oil in diesel engines.

There must be following policy to increase oil palm' productivity and production, and managing UCO in order to avoid food insecurity of cooking oil and to achieved sustainability of the downstream biodiesel. Hence, biodiesel downstream policies that support energy security should not compete with food security.

Future work needs to be done, particularly investigating government policies in the development of downstream biodiesel. Economic models capturing UCO as an alternative source of biodiesel material are also needed to be assessed. Those are needed to contribute maximally to the achievement of national energy security.

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