The Economic Impacts

of European Union Deforestation-free Regulation on Indonesia’s Palm Oil Sector

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It is not the knowledge which should come to you, it is you should come to the knowledge. – Imam Malik

Abstract

In 2022, the European Union (EU) introduced a significant environmental policy known as the EU Deforestation-free Regulation (EUDR). This policy aims to reduce the impact of imported products on deforestation, focusing specifically on six commodities that are known for their substantial contribution to deforestation. These commodities include palm oil, rubber, cocoa, wood, coffee, and maize. Out of all these commodities, palm oil is the most significant contributor to deforestation. Therefore, it is crucial to study the effects of EUDR on palm oil's economy and environment since this policy will be implemented no later than 30th December 2024, and there is limited research on this matter. This study evaluates the impact of EUDR on the Indonesian palm oil sector and on the EU as a consumer of these products. Three scenarios are examined, including the impact of decreasing demand in the EU, the increase in the cost of Certified Sustainable Palm Oil (CSPO), and the increase in marginal cost in Indonesia and the rest of the world. The research findings indicate that in the first scenario, there is a shift from regulated to less regulated countries. Additionally, there are price changes in response to the EUDR and a decrease in trade flow in the market, leading to the reduction of greenhouse gas (GHG) emissions.

Keywords: *EUDR, Palm Oil, Trade Flow, Pricing, GHG emissions.*

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INTRODUCTION

1.1 Background

Palm oil plays a crucial role globally, supplying approximately 40% of the world's traded vegetable oil and serving as a crucial dietary component for over three billion people, particularly in Asia and Africa (Lye Chew et al., 2021; Murphy et al., 2021). In addition, the EU, as one of the major importers of palm oil, is a leading player in this market, especially for crude palm oil (CPO), importing around 1.6 million tons (BPS, 2021). Indonesia and Malaysia are the biggest palm oil producers, bringing significant economic benefits (Khatun et al., 2017; Qaim et al., 2020; Zhao et al., 2023). However, palm oil production has negative environmental impacts like deforestation and peatland conversion, which are significant concerns (European Commission, 2023).

In response, in 2022, the European Union (EU) introduced a significant environmental policy, the EU Deforestation-free Regulation (EUDR), to curb the deforestation impacts of imported products (European Commission, 2023). This regulation specifically targets six commodities known for their substantial contribution to deforestation: palm oil, rubber, cocoa, wood, coffee, and maize (European Commission, 2023). Among these, palm oil is the most significant contributor, responsible for 34% of global deforestation between 2008 and 2011, leading to 4,300 km^2 of forest loss (Halleux, 2023; Russell, 2020a). Therefore, it is of great significance to study the effect of EUDR in palm oil on the economy and environment since this policy will be implemented no later than 30th December 2024 (European Commission, 2023), and the research about this is still limited.

Previous studies have examined policies' impact in mitigating deforestation in producing countries, such as the European Timber Regulation (EUTR) (Partzsch et al., 2023) and the demand-side restriction on high-deforestation commodities (Busch et al., 2022). The results of these studies indicate there will merely be a shift in exports to less regulated countries (Busch et al., 2022; Partzsch et al., 2023). Hence, it is likely that the implementation of the EUDR might lead to changes in trade patterns (Corona et al., 2023). A study compared the EUTR and EUDR and suggested that implementing EUDR could also lead to trade shifting to less regulated countries (Köthke et al., 2023), and Wolfmayr stated that the EUDR would also change trade patterns (Wolfmayr et al., 2024). However, the effect of such a shift on EUDR has not yet been scientifically validated, and it remains to be seen to what extent this may cause trade shifts in favor of countries with less regulation (Köthke et al., 2023).

It is important to note that changing climate policies not only affect trade flow but also impact prices. Hence, since EUDR is a new policy, examining other existing environmental policies as a framework for this study is crucial. The study by Zhou et al. (2023) stated that climate policy uncertainty leads to higher oil prices, while the other study by Rougieux and Jonsson (2021) on EUTR shows that after EUTR came into force, the import prices of timber in the EU increased. Then, when discussing the price of a product, it is also essential to consider its production cost. A study on climate policy, specifically in the EUDR, found that producers who face stricter restrictions when placing their goods on the EU market may experience higher production costs. As a result, the prices of affected products from third countries (such as Indonesia and Malaysia) could increase (Wolfmayr et al., 2024). Therefore, it remains open to how strongly the EUDR will affect the prices (Köthke et al., 2023).

Lastly, the implementation of EUDR is expected to impact the environment positively. This new regulation is projected to reduce global greenhouse gas emissions (GHG) and also decrease the EU's contribution to global deforestation (Zhunusova et al., 2022a). However, there is still limited research on assessing the impact of EUDR on the environment. It is essential to consider other studies assessing environmental policies, such as research from China, which found that imposing environmental regulations reduced emissions (Cheng et al., 2017). Another study suggests that reducing the consumption of deforestation-risk products could contribute to the EUDR's goal of preventing deforestation (Wolfmayr et al., 2024). To have a significant positive impact on the environment, the EUDR will need policy interventions, such as the implementation of certification schemes, as Pendrill et al., (2019) suggested. To assess the impact of EUDR, sustainable palm oil certifications, such as Indonesian Sustainable Palm Oil (ISPO), Malaysian Sustainable Palm Oil (MSPO), and the Roundtable of Sustainable Palm Oil (RSPO), can be helpful to (Schouten et al., 2023; Xin et al., 2022). Europe leads the consumption of RSPO-certified sustainable palm oil (CSPO), with 93% of imports being sustainable (EPOA et al., 2022). Nevertheless, it is still uncertain to what extent EUDR will affect GHG emissions reduction.

Therefore, we have concluded that although there has been progress in understanding the effects of environmental or climate regulations, areas still require further study. This is because EUDR has not yet been implemented, resulting in a lack of knowledge regarding its impact on the economy and the environment. However, some research has been conducted on climate policies such as the European Union Timber Regulation (EUTR) that do not focus on the EUDR and do not focus on palm oil (Partzsch et al., 2023; Rougieux & Jonsson, 2021). Hence, it is essential to scientifically validate the effect of EUDR on trade shifts and prices, as well as determine how much it can reduce GHG emissions in line with its goal of reducing the consumption of deforestation-risk products and reducing GHG emissions. By addressing these areas, the research seeks to contribute valuable insights into the EUDR's multifaceted impact, thereby informing policy discussions and future research directions in environmental economics and trade regulation.

1.2 Objective of the Research

This research aims to examine the economic implications of the EUDR on the palm oil industry in Indonesia. The study will focus on the impact on trade flows, prices, and environmental effects. The first objective is to determine any changes in trade flows between Indonesia (IND), the rest of the world (ROW)/Malaysia, and the European Union (EU). It is assumed that there would be a shift in trade patterns. The third objective is to assess the potential environmental impacts of the EUDR by investigating whether there will be GHG emissions reduction or deforestation. It is assumed that there would be a reduction in GHG emissions. The second objective is to examine any changes in prices. Understanding these changes will help devise future strategies for addressing the EUDR. The assumption is that there would be a decrease in the price of palm oil as a decrease in demand for palm oil in the EU or a decrease in the consumption of palm oil. Another assumption is that increasing CSPO costs and marginal cost (MC) will increase the price of imported palm oil.

1.3 Research Questions

The research focuses on the following questions:

1. What is the impact of the EUDR on the palm oil industry trade activity between Indonesia, Europe, and the rest of the world?
2. How has the implementation of the EUDR affected the pricing of palm oil in Indonesia, Europe, and the rest of the world?
3. What is the environmental impact of the EUDR?

1.4 Content Overview

The research commences with an Introduction section that clearly outlines the problem definition and research objective, which is to evaluate the impact of EUDR on Indonesia's palm oil industry. The subsequent chapter is a literature review that examines the current state of palm oil, EUDR and the gap in research, and the Partial Equilibrium Model. Following this is the research methodology, which employs the Partial Equilibrium Model. Data collection and calibration are then necessary to facilitate the data for running the model. Chapter 6 presents the research results based on three research questions, and the final chapter is a general discussion that summarizes the research findings.

LITERATURE REVIEW

2.1 Palm Oil Condition

Palm oil plays a crucial role globally, supplying approximately 40% of the world's traded vegetable oil (Murphy et al., 2021). It is also a vital dietary component for over three billion people, mainly in Asia and Africa, with a combined consumption of around 57 million tons, accounting for 82% of the total palm oil consumed (Lye Chew et al., 2021). Additionally, palm oil is widely used in non-food uses, including in cleansing and sanitizing products, as well as many packaged products sold in supermarkets (Murphy et al., 2021; WWF, 2023). Given its versatility and economic benefits, palm oil has become the world's most widely used vegetable oil, serving as an essential source of food and energy for many developing and underdeveloped countries. As the global population and economy grow, the demand for palm oil is expected to rise (Lye Chew et al., 2021; Russell, 2020b). However, expanding palm oil plantations and increasing consumption threaten some of the planet's most important and vulnerable ecosystems, putting tropical rainforests at risk of destruction (Russell, 2020b; WWF, 2023).

The total forest area in the world is 4.06 billion hectares (ha), which is 31% of the total land area (FAO, 2020b). Unfortunately, since 1990, deforestation has led to the loss of approximately 420 million hectares of forests. However, the forest loss rate has declined substantially (2015-2020) (FAO, 2020b). Africa and South America have the highest annual rate of net forest loss, while Asia had the top net gain of forest area in 2010–2020, followed by Oceania and Europe (FAO, 2020b).

Deforestation is still happening but at a slower rate than before. Almost 90% of deforestation worldwide is due to agricultural expansion (FAO, 2020a). Deforestation is converting forests to other land uses, such as agriculture, mining, urban, and infrastructure. Cropland expansion is the cause of almost 50% of forest loss (FAO, 2020a). Over 75% of the forest area loss in Africa and Asia is due to conversion to cropland (FAO, 2020a). Many tropical forests are being converted to agricultural use to produce traded goods. The European Union (EU) is one of the importers of these goods, and its consumption is responsible for about 10% of global deforestation, most of the goods are palm oil and soya, which account for more than two-thirds of it (European Parliament, 2023). Regarding palm oil, the EU is the second biggest importer of CPO (Crude Palm Oil), with around 1.6 million tons, and the value is 1.08 million US$ (BPS, 2021). Indonesia and Malaysia are the world's largest palm oil producers, with a total production of 92 million tons, of which Indonesia alone produces 52 million tons, and Malaysia produces 23 million tons (Coordinating Ministry of Economic Affairs Indonesia, 2023). Palm oil in Indonesia is a vital commodity, and any changes in regulations related to its trade can significantly impact Indonesia's economy.

2.2 European Union Deforestation Regulation (EUDR)

The EU plays a vital role in global deforestation and forest degradation by consuming these products. However, the current legislative framework is inadequate to mitigate the problem of EU-driven deforestation (European Parliament, 2023). To tackle this issue, the European Parliament has proposed a new regulation called the European Union Deforestation-free Regulation (EUDR). This regulation aims to decrease the use of products linked to deforestation and promote the trade of lawful and deforestation-free goods in the EU (European Commission, 2021). The EUDR restricts exporting products to the EU market that do not obey its legality and sustainability requirements (FSC, 2023). Companies must handle due diligence, ensuring that the products they source are lawful and are not linked to land that has been deforested after 31 December 2020 (FSC, 2023). The following are the main products imported by the EU from deforested land: Palm oil 34%, Soya 32.8%, Wood 8.6%, Cocoa 7.5%, Coffee 7%, Rubber 3.4%, and Maize 1.6% (Halleux, 2023).

The EUDR, set to be implemented by the end of 2024, is a relatively new area of interest with limited research available. While there have been some studies conducted on its effects on smallholders, indigenous populations, local communities (Zhunusova et al., 2022b), and private sector and government entities (Köthke et al., 2023), and also the political coalition (Berning & Sotirov, 2024). There remains a lack of detailed analysis regarding its economic and environmental impacts, particularly in terms of trade, pricing, and GHG emissions. Although one study has delved into the topics of trade and social welfare (Wolfmayr et al., 2024), it did not specifically examine how these matters affect Indonesia in specific instead centering on Austria and the EU. Other research centralizes Brazil on examining compliance readiness in supply chains for cattle, cocoa, coffee, palm oil, soybean, and tropical timber and does not address the trade and environment implications (Cesar de Oliveira et al., 2024). Recognizing this gap, our study aims to explore how the EUDR influences the economy, trade, and pricing and its environmental effects on GHG emissions, offering new insights into its broader impacts.

According to a recent study by Wolfmayr (2024), EUDR has a significant impact on trade and social welfare in various countries, including Indonesia. The study uses the Kiel Institute Trade Policy Evaluation Model (KITE) to analyze the effects of the EUDR on some such as the USA, China, and Brazil. The KITE model is a computable general equilibrium model that enables researchers to assess long-term trade effects, including trade diversion and third-market effects, as well as production, price, welfare, and carbon emissions effects at the sectoral and economic levels. While the study focuses primarily on Austria and the EU, it also includes these other countries because they are among the top countries from which the EU sources deforestation-free products as defined by the EUDR. The study found that the implementation of the EUDR has little effect on trade and welfare, and expanding its product coverage may enhance its positive impact. However, if operators in major EU trading partners do not comply with the EUDR and are banned from the EU Single Market, there could be declines in trade and welfare. The impact of the EUDR will depend on effective implementation in cooperation with key trading partners, mainly in developing countries, to reduce negative impacts and increase positive impacts on forest conservation, restoration, and sustainable land use.

In Wolfmayr's study from 2024, it was found that the impact of EUDR was focused on the long-term and demonstrated the effects of its implementation in various commodities such as poultry, swine, sheep, goats, maize, and forest-risk products. However, this research will concentrate on palm oil, which is the primary contributor to deforestation. The goal is to determine the specific impact of EUDR on the economy and environment in relation to this commodity. As Wolfmayr's research has shown that the implementation of EUDR can reduce deforestation levels, this study focuses on greenhouse gas emissions reduction and deforestation aspect resulting from several shocks that will be tested. The aim is to evaluate the specific impact of EUDR on palm oil, and to do so, we will assess this research through Partial Equilibrium Models (PEMs).

2.3 Partial Equilibrium Models (PEMs)

Partial equilibrium models describe market outcomes by depicting the underlying behavioural relations (Bouman et al., 2000). Changes due to policies can be traced back to their effects on consumption and production decisions, allowing for analysis of price and substitution effects (Bouman et al., 2000). PEMs capture supply and demand interaction where commodity prices are endogenous to shock or policy simulated (Latta et al., 2013). They are useful for scenario analysis highlighting the underlying market dynamics of policies or shocks (Boutesteijn et al., 2017; Korting & Just, 2017; Latta et al., 2013; Tuinstra et al., 2014). These models are particularly suited to study trade-offs between economic and environmental goals (Alig et al., 1998; Latta et al., 2013), and valuate market modeling and instruments for regulating flows for environmental and economic outcomes (Bouman et al., 2000). Hence, in this study assessing the EUDR impacts in the economy and environment is through PEMs. Parts of the economy and the *ceteris paribus* assumption are applied to the rest of the economy, meaning it remains unaffected by changes (Zhu, 2023). This approach can also be integrated with environmental issues for a more comprehensive analysis. Some studies have used this approach to assess the impact of policies or market shocks on the environment (Luthfi & Kaneko, 2016; Saikkonen et al., 2014).

In this study also, we will use descriptive analysis to assess how EUDR affects the environment, especially GHG emission impact. Unlike taxes or levies, the EUDR has no specific sanction for non-compliance, making it impossible to include in PEMs. Therefore, we will conduct a separate environmental analysis, which will be carried out in parallel with the PEMs analysis. After obtaining the results of the PEMs in the trade flow, we will analyze the impact of the EUDR on the palm oil industry.

PEMs offers a straightforward and adaptable approach to determine equilibrium prices by matching demand and supply (Board, 2009; Zhu, 2023). However, the major limitation of PEM approaches is that they assume anything not explicitly modeled to be constant (Zhu, 2023). In reality, there are various effects on other markets and agents, and feedback effects that can influence the model. Therefore, this research will only be able to demonstrate the impact of EUDR solely on palm oil and only in three markets - Indonesia, The Rest of The World (Malaysia), and Europe.

RESEARCH METHODOLOGY

To answer the research questions number (1) and (2), GAMS (General Algebraic Modeling System) was used to run the models for this research to evaluate the changes in trade and prices. Subsequently, to answer the research question (3), we conducted a descriptive data analysis to investigate the decline or increase in demand for palm oil from producing countries and how this decline or increase affects the reduction or increase in GHG throughout the CPO supply chain. Hence, the first step to assess questions (1) and (2) is designing the partial equilibrium model for Indonesia and the rest of the world as producer countries and the EU as the consumer country and, after that, creating scenarios to know the impact of EUDR in trade and price.

3.1 Designing the Partial Equilibrium Model for Indonesia as a Producer Country.

Based on the partial equilibrium theory, this research builds upon the partial equilibrium model for the palm oil sector in Indonesia. The total profit of the palm oil sector is calculated by adding up the revenue generated from palm oil exports to the EU and the rest of the world, along with the revenue generated from the domestic consumption of CPO in Indonesia. From the total cost of producing oil palm, which includes other expenses such as transportation costs incurred in sending the product to the market and CSPO expenses, this figure is then subtracted.

Certified sustainable palm oil (CSPO) is responsible for 93% of the majority of demand from companies in the EU (EPOA et al., 2022). Therefore, we consider it to be the major share demand of the EU through certified sustainable palm oil practices. Although there are certification schemes in producer and importer countries, we focus on the EU as an importer and their demand for CSPO as evidence of sustainable palm oil cultivation.

The research focuses on Indonesia as a palm oil producer while Malaysia represents the rest of the world as a producer and consumer of palm oil. As a major price-maker, Indonesia's palm oil sector influences the world market price. The profit maximization model for the palm oil sector, including CSPO, can be derived as follows:

$$max\ \pi_{IND} = P_{EU}(Q_{EU})q_{IND}^{EU} + P_{ROW}(Q_{ROW})q_{IND}^{ROW} + P_{IND}(Q_{IND})q_{IND}^{IND} - C(q_{IND}^{EU} + q_{IND}^{ROW} + q_{IND}^{IND}) - t_{IND}^{EU}.q_{IND}^{EU} - t_{IND}^{ROW}.q_{IND}^{ROW} - CSPOq_{IND}^{EU} \quad (1)$$

In this equation, the variables used are as follows: The subscript P represents the price of CPO in the European Union, the rest of the world, and Indonesia. P (Q) in this equation is the function of the price that is determined by the market demand function, and the function of price in the linear demand function is $P(Q) = a - bQ$, where a and b are constants, and the price depends on the total demand quantity Q produced by the producer of palm oil and the equation shown below in equation (2), (3), and (4). The variable Q represents the demand for palm oil in these regions. At the same time, the variable q represents the quantity of palm oil exported by Indonesia to the EU and the rest of the world and also refers to the consumption of Indonesian palm oil. The variable C denotes production cost, and the variable t refers to transport cost. The term "CSPO" stands for the investment made by industries in the sustainable palm oil certificate issued by RSPO (Roundtable on Sustainable Palm Oil). The purpose of undertaking CSPO certification (a non-legislative regulation) is to enhance the competitiveness of industries in the global market and get access to the EU market.

$$Q_{EU} = q_{IND}^{EU} + q_{ROW}^{EU} \quad (2)$$

$$Q_{ROW} = q_{IND}^{ROW} + q_{ROW}^{ROW} \quad (3)$$

$$Q_{IND} = q_{IND}^{IND} + q_{ROW}^{IND} \quad (4)$$

Once the trading activity is implemented, it becomes crucial to identify the most profitable markets for trading. Therefore, the corresponding first-order condition is below.

$$\frac{\partial \pi_{IND}}{\partial q_{IND}^{EU}} = \frac{dP_{EU}}{dQ_{EU}} q_{IND}^{EU} + P_{EU} - MC_{IND} - t_{IND}^{EU} - CSPO = 0 \quad (5)$$

$$\frac{\partial \pi_{IND}}{\partial q_{IND}^{ROW}} = \frac{dP_{ROW}}{dQ_{ROW}} q_{IND}^{ROW} + P_{ROW} - MC_{IND} - t_{IND}^{ROW} = 0 \quad (6)$$

$$\frac{\partial \pi_{IND}}{\partial q_{IND}^{IND}} = \frac{dP_{IND}}{dQ_{IND}} q_{IND}^{IND} + P_{IND} - MC_{IND} = 0 \quad (7)$$

3.2 Designing the Partial Equilibrium Model for The Rest of The World (Malaysia)

In an oligopoly market, a few firms or countries dominate the industry. Malaysia is the second larger producer of palm oil globally. Hence, Malaysia also has the possibility to influence the price in the market as a price maker. To secure the maximum share of palm oil and increase profits in this sector, it is important to determine the optimal quantity of palm oil to export. The equation of maximization profit is as follows.

$$max\ \pi_{ROW} = P_{EU}(Q_{EU})q_{ROW}^{EU} + P_{ROW}(Q_{ROW})q_{ROW}^{ROW} + P_{IND}(Q_{IND})q_{ROW}^{IND} - C(q_{ROW}^{EU} + q_{ROW}^{ROW} + q_{ROW}^{IND}) - t_{ROW}^{EU}.q_{ROW}^{EU} - t_{ROW}^{IND}.q_{ROW}^{IND} - CSPOq_{ROW}^{EU} \quad (8)$$

$$Q_{EU} = q_{IND}^{EU} + q_{ROW}^{EU} \quad (9)$$

$$Q_{ROW} = q_{IND}^{ROW} + q_{ROW}^{ROW} \quad (10)$$

$$Q_{IND} = q_{IND}^{IND} + q_{ROW}^{IND} \quad (11)$$

In the partial equilibrium model for the rest of the world, the quantity of palm oil produced differs from that exported by Indonesia to the EU. This difference affects the basic model and the maximization of total profit. In addition, the rest of the world also requires Certified Sustainable Palm Oil (CSPO), which is why it is included in equation (8). Here are the corresponding first-order conditions:

$$\frac{\partial \pi_{ROW}}{\partial q_{ROW}^{EU}} = \frac{dP_{EU}}{dQ_{EU}} q_{ROW}^{EU} + P_{EU} - MC_{ROW} - t_{ROW}^{EU} - CSPO = 0 \quad (12)$$

$$\frac{\partial \pi_{ROW}}{\partial q_{ROW}^{IND}} = \frac{dP_{IND}}{dQ_{IND}} q_{ROW}^{IND} + P_{IND} - MC_{ROW} - t_{ROW}^{IND} = 0 \quad (13)$$

$$\frac{\partial \pi_{ROW}}{\partial q_{ROW}^{ROW}} = \frac{dP_{ROW}}{dQ_{ROW}} q_{ROW}^{ROW} + P_{ROW} - MC_{ROW} = 0 \quad (14)$$

3.3 The policy analysis of EUDR

It is mandatory to include the EUDR statement in the due diligence statement and failing to do so will result in fines. In this analysis, we will conduct a descriptive analysis and literature review of the results obtained from the partial equilibrium model. For instance, if half of the supply is non-compliant with the regulations, we will determine the effect it will have on the world economy. In addition, the environmental effect of doing so, such as the level of carbon emission.

Lastly, if palm oil traders fail to comply with the Due Diligence statement, they will be fined. The fine for EUDR is 4%, while the fine for Due Diligence is 5%. The fine is based on the company's turnover. EU-based companies fall into three categories that must comply with these regulations. The first category includes companies in the EU with up to 250 employees and a worldwide turnover of more than or equal to €40 million. The second category includes parent companies in the EU with over 500 employees and a worldwide turnover of more than €150 million. The last category includes non-EU companies with a turnover above €150 million. However, in this case, we assumed all the producers from Indonesia and the rest of the world comply with EUDR.

DATA COLLECTION

We use data from various sources and focus on producing palm oil CPO (Crude Palm Oil) and its derivatives (others palm oil), excluding kernel and its derivatives. For Indonesia, we obtained the data from Statistic Indonesia 2022 (Statistics Indonesia, 2023), which covers the production, consumption, export to the EU and Malaysia, import, and price of palm oil. The data for Malaysia, which is used as a reference for the rest of the world, is obtained from MPOC or Malaysia Palm Oil Council 2022 and CPOPC or Council of Palm Oil Producing Countries (CPOPC, 2024a, 2024c, 2024b; MPOC, 2023), it covers the production, consumption, export to the EU and Indonesia, import, and price of palm oil. To obtain the price of palm oil in the EU, we relied on the data from CIF Rotterdam 2022 (CIF Rotterdam, 2024). We only had the data for CPO price from CIF Rotterdam. To get the price for other types of palm oil, we added a 14% increase to the Indonesian palm oil price for CPO. Therefore, in the end, the price of CPO in Europe is 1246 Euros/ton. Here is the data we collected:

Table 1. Data for palm oil production, consumption, export, import, and price in Indonesia, the rest of the world, and Europe in 2022.

		Indonesia	**ROW (Malaysia)**	**Europe (EU)**
Production (Million MT)		46.820	18.453	0
consumption (Million MT)		18.936	3.282	6.406
Export (Million MT)	Indonesia (IND)		1.249	2.877
	ROW (Malaysia)	0.0002		1.470
Import (Million MT)	Indonesia (IND)		0.0002	0
	ROW (Malaysia)	1.249		1.470
Price (Euro/MT)		1013	919.4	1246

Source: Statistics Indonesia (2023), MPOC (2023), CPOPC (2024a, 2024b, 2024c), CIF Rotterdam (2024).

MT: Metric Tons

Regarding the cost of production, we use data on the cost of production for palm oil in Indonesia and Malaysia (as in the rest of the world) from United Plantations Berhad (2022). The cost of production of Indonesia's palm oil is 317.62 Euro/MT, and for ROW, it is 323.09 Euro/MT. When it comes to the cost of transportation, it depends on where the palm oil is being shipped from and where it is being shipped to. In Indonesia, four ports export crude palm oil (CPO): Belawan, Jakarta, Semarang, and Surabaya. Surabaya port exports the most palm oil compared to the other ports so that we will focus on this port as the initial point of shipment to the Netherlands and Malaysia (ROW) as the final destination. The transportation costs from Indonesia to Malaysia and the Netherlands will be determined using data from previous research conducted by Zahraee and Domnik. The cost of transportation from Indonesia to the EU is 88.26 Euro/MT, and the cost of transportation from Indonesia to the rest of the world (ROW) is 27.59 Euro/MT, which does not include the tariff (Domnik et al., 2019; Zahraee et al., 2021). Later calibration of transportation costs from ROW to Indonesia and the EU will be done.

The export tariff for goods of CPO leaving Indonesia and heading to Malaysia (or the rest of the world) and the EU will be 132.28 Euro/MT in 2022. This tariff is calculated based on the current price of CPO 1013 Euro per metric ton, which places Indonesia in group nine. Therefore, the tariff amount that needs to be paid for each metric ton of goods exported will be 144 USD, which is equivalent to 132.28 Euro/MT (Indonesian Ministry of Finance, 2022). For Malaysia, the export tariff to Indonesia and the EU is 8% of the current price (Malaysian Royal Customs Department, 2022). This is because the price in 2022 is above 3450 MYR, equivalent to 1006 Euro/MT (4698 MYR). Therefore, the export duty that needs to be paid is 80.48 Euros per metric ton. For import tariff to the EU, the tariff is 50.65 Euro/MT (European Commission, 2024), and the import tariff to ROW is 25.325 Euro/MT (Malaysian Royal Customs Department, 2022). Additionally, after we know the tariff, we calculate the total transportation cost from Indonesia to the EU and ROW. The total transportation cost in this research includes the transportation cost, export and import tariffs.

The last is the cost of CSPO as certified for sustainable palm oil. Certification costs are limited to certified and prospective growers. Initial certification estimates range from US$1.2/ha to US$402.7/ha, which includes certification and maintenance expenses. The data was obtained from the study of Tey 2020 (Tey et al., 2021). According to Tey's study, the cost of certification and maintenance for each metric ton of CPO in the Indonesia and Malaysia plantations is 3.60 euros.

CALIBRATION DATA

This study calibrated the model defined by the system of equations (1)-(14) to an EUDR implementation using the available data. Firstly, this study calibrates the data to find the constant values a and b for modeling. The constants are generated from the model equations (5), (6), and (7).

$$b_{IND} = \frac{-MC_{IND}+P_{IND}}{q_{IND}^{IND}}$$

$$b_{ROW} = \frac{-MC_{IND}-t_{IND}^{ROW}+P_{ROW}}{q_{IND}^{ROW}}$$

$$b_{EU} = \frac{-MC_{IND}-t_{IND}^{EU}-CSPO+P_{EU}}{q_{IND}^{EU}}$$

MC denotes Marginal Cost, and was gained from the calculation of Average Cost (AC), where AC = 1/2 AQ or equal to the total cost per unit where $C = 1/2AQ_{IND}^2$, hence $MC_{IND} = 2AC_{IND}$ and $MC_{ROW} = 2AC_{ROW}$. After finding b, we moved to finding the little a and A capital. The constant of little a found from the formula of the linear demand function is $P(Q) = a - bQ$. For A capital we were obtained from the average cost formula.

$$a_{IND} = P_{IND} + b_{IND}Q_{IND}$$

$$a_{ROW} = P_{ROW} + b_{ROW}Q_{ROW}$$

$$a_{EU} = P_{EU} + b_{EU}Q_{EU}$$

$$A_{IND} = \frac{2AC_{IND}}{Q_{TotalIND}}$$

$$A_{ROW} = \frac{2AC_{ROW}}{Q_{TotalROW}}$$

Q total IND is from the total production in IND which is $Q_{TotalIND} = q_{IND}^{EU} + q_{IND}^{ROW} + q_{IND}^{IND}$. For Q total ROW from the total production of palm oil in ROW which is $Q_{TotalROW} = q_{ROW}^{EU} + q_{ROW}^{IND} + q_{ROW}^{ROW}$. After that finding the elasticity to know how sensitive the quantity demanded of palm oil is to a change in its price. The elasticity demand is denoted by the script ε_D. In this research, there are three elasticity demand values for Indonesia, the rest of the world, and Europe that we need to find.

$$\varepsilon_{D\_IND} = -\frac{1}{b_{IND}} . \frac{P_{IND}}{Q_{IND}}$$

$$\varepsilon_{D\_ROW} = -\frac{1}{b_{ROW}}.\frac{P_{ROW}}{Q_{ROW}}$$

$$\varepsilon_{D\_EU} = -\frac{1}{b_{EU}}.\frac{P_{EU}}{Q_{EU}}$$

The $-\frac{1}{b_{EU}}$ is from:

$$P(Q) = a - bQ$$

$$\frac{dP}{dQ} = - b$$

$$\frac{dQ}{dP} = - \frac{1}{b}$$

$$\varepsilon_D = \frac{dQ}{dP}.\frac{P}{Q}$$

$$\varepsilon_D = -\frac{1}{b}.\frac{P_0}{Q_0}$$

After calibrating all of parameters and elasticity, in the first scenario, when the demand for palm oil decreases by 5% and 10% respectively in the EU, the export activity from IND (India) and ROW (Rest of the World) to the EU experiences a decrease because of the reduced demand or consumption of palm oil in the EU. This decrease in demand affects the supply of palm oil, leading to a decrease in its price. The price decreases because the supply remains the same while the demand decreases. Meanwhile, the demand for palm oil in IND and ROW witnesses an increase, leading to an increase in supply in these regions. In the last is calibrating the transportation cost from ROW. We calibrate the data from the equations (12), (13), and (14). However, to making balance the formula, we add transportation cost from ROW to ROW, t_{ROW}^{ROW}, in the equation (14). Hence, below are the formulas for calculating the transportation cost from ROW.

$$t_{ROW}^{EU} = -b_{EU}q_{ROW}^{EU} + P_{EU} - MC_{ROW} - CSPO$$
$$t_{ROW}^{IND} = -b_{IND}q_{ROW}^{IND} + P_{IND} - MC_{ROW}$$
$$t_{ROW}^{ROW} = -b_{ROW}q_{ROW}^{ROW} + P_{ROW} - MC_{ROW}$$

Here all the value from collecting the data and from calibrating the data:

Table 2. Data collection and calibration

Parameter/Variable	Value	Unit	Source
Elasticities			
Palm oil demand in IND	-2.681571503		own calculation
Palm oil demand in ROW	-2.56037354		own calculation
Palm oil demand in EU	-2.454444004		own calculation
Parameters			
a IND	1390.763561		own calculation
a ROW	1278.488229		own calculation
a EU	1753.650612		own calculation
b IND	19.94930292		own calculation
b ROW	79.25753473		own calculation
b EU	116.7902117		own calculation
A capital IND	27.54566853		own calculation
A capital ROW	135.9755321		own calculation
Cost and Tariff			
Transportation Cost IND to EU	88.26	Euro/MT	(Domnik et al., 2019)
Transportation Cost IND to ROW	27.59	Euro/MT	(Zahraee et al., 2021)
Total Transportation Cost IND to EU	271.19	Euro/MT	own calculation
Total Transportation Cost IND to ROW	185.195	Euro/MT	own calculation
Transportation Cost ROW to EU	435.8383888	Euro/MT	own calculation
Transportation Cost ROW to IND	366.816439	Euro/MT	own calculation
Transportation Cost ROW to ROW	13.09677101	Euro/MT	own calculation
CSPO Cost	3.600999479	Euro/MT	(Tey et al., 2021)
Export Tariff IND	132.28	Euro/MT	(Indonesian Ministry of Finance, 2022)
Import Tariff EU	50.65	Euro/MT	(European Commission, 2024)
Import Tariff ROW	25.325	Euro/MT	(Malaysian Royal Customs Department, 2022)
Cost of Production in IND	317.62	Euro/MT	(United Plantations Berhad, 2023)
Cost of production in ROW	323.09	Euro/MT	(United Plantations Berhad, 2023)
Prices			
Palm oil price in IND	1013	Euro/MT	(Statistics Indonesia, 2023)
Plam oil price in ROW	919.4	Euro/MT	(MPOC, 2023)
Plam oil price in EU	1246	Euro/MT	(CIF Rotterdam, 2024)
Quantities			
Demand palm oil in IND	18.9361785	million MT	(CPOPC, 2024b)
Demand palm oil in ROW	4.530651	million MT	(CPOPC, 2024b)
Demand palm oil in EU	4.346688	million MT	(CPOPC, 2024c)
Quantity exported from IND to EU	2.876688	million MT	(Statistics Indonesia, 2023)
Quantity exported from IND to ROW	1.248651	million MT	(Statistics Indonesia, 2023)
Quantity consumed in IND	18.936	million MT	(Statistics Indonesia, 2023)
Quantity exported from ROW to EU	1.47	million MT	(MPOC, 2023)
Quantity exported from ROW to IND	0.0001785	million MT	(MPOC, 2023)
Quantity consumed in ROW	3.282	million MT	(MPOC, 2023)

IND: Indonesia, ROW: The rest of the world, EU: European Union, CSPO: Certified Sustainable Palm Oil, MT: Metric Tons.

RESULTS

As a major price-maker, Indonesia's palm oil sector influences the world market price. Based on the calculation in this research the demand elasticity for palm oil differs in different regions. In Indonesia, it is -2.681571503, in the rest of the world, it is -2.56037354, and in the European Union, it is -2.454444004. A 1% rise in palm oil price will lead to a decrease in demand of approximately 2.68% in Indonesia, 2.56% in the rest of the world, and 2.45% in the EU. This responsiveness is crucial for understanding the broader economic and environmental implications of the EUDR on the palm oil industry.

6.1 Changes in trading activity and pricing in response to EUDR

In order to analyze the potential changes of three markets (IND, ROW, and EU) in trade flow and pricing, we have implemented a simulation of the PEMs in GAMS. Our simulation involves three scenarios, the first of which involves a 5%, 10%, and 20% decrease in demand for palm oil in the EU, while the second scenario involves a 5%, 10%, and 20% increase in the cost of CSPO, and the last is an increase of 5%, 10%, and 20% in the Marginal Cost in both IND and ROW. Below are the results of all three scenarios.

6.1.1 Scenario 1: Decreasing the Demand for Palm Oil in the EU

The rationale behind these scenarios is based on the assumption that the implementation of EUDR will lead to a decline in demand for palm oil in the EU. According to Pendrill et al., (2019), reducing the demand for forest-risk commodities, as intended by the EUDR, can potentially decrease deforestation and forest degradation not only in the EU's major trading partners but also worldwide. Therefore, we assume that the decrease in demand in the EU is a shock that can help understand the impact of EUDR.

Table 3. Change in market prices, quantities, profit, and demand due to a decrease in the EU demand of 5%, 10%, and 20%.

		Decreasing demand in the EU		
		5%	**10%**	**20%**
	Baseline	% Change relative to baseline		
Profit IND	15568.057	-0.52	-1.10	-2.25
Profit ROW	2684.461	-1.15	-2.29	-4.56
Prices				
Palm oil price in IND	1013	-0.11	-0.23	-0.48
Plam oil price in ROW	919.4	-0.12	-0.25	-0.52
Plam oil price in EU	1246	-0.78	-1.60	-3.32
Quantities				
Demand palm oil in IND	18.936	0.30	0.61	1.28
Demand palm oil in ROW	4.531	0.31	0.64	1.32
Demand palm oil in EU	4.347	-3.17	-6.49	-13.48

		Decreasing demand in the EU		
		5%	**10%**	**20%**
	Baseline	% Change relative to baseline		
Quantity exported from IND to EU	2.877	-2.50	-5.07	-10.53
Quantity exported from IND to ROW	1.249	0.24	0.56	0.56
Quantity consumed in IND	18.936	0.08	0.16	0.34
Quantity exported from ROW to EU	1.47	-4.56	-9.25	-19.25
Quantity exported from ROW to IND	0.0001785	23429	47519	99059
Quantity consumed in ROW	3.282	0.34	0.64	1.37

Source: *GAMS result and own calculation*
IND: Indonesia, ROW: The rest of the world, EU: European Union, MT: Metric Tons.

In the first scenario, if the demand for palm oil decreases by 5%, 10%, and 20% respectively in the EU, the export activity from IND and ROW to the EU will decrease due to the reduced demand for palm oil. This decrease in demand affects the overall supply of palm oil, eventually leading to a decrease in its price and its profit. The biggest decline in export activity is from the ROW to the EU, which decreases by 19.25%. At the same time, the demand for palm oil in IND and ROW increases by 0.30%, 0.61%, and 1.28% for IND, and 0.31%, 0.64%, and 1.32% for ROW. This increase in demand leads to an increase in the supply of palm oil in these regions. The biggest increase is the export from ROW to IND, which reaches 99059% in the 20% increase in demand of EU.

6.1.2 Scenario 2: Increasing the Cost of CSPO

Based on our analysis, we have assumed that the implementation of the EUDR would lead to a decrease in palm oil demand in the EU market as a first scenario and the result is above. However, we have also considered the impact of EUDR on the cost of CSPO. We anticipate that the voluntary certification process will encourage producers to make palm oil more sustainable and apply this certification, leading to increased CSPO costs. In addition, EUDR will still need policy interventions such as the implementation of certification schemes to have an important positive impact on deforestation and forest degradation in EU trading partner countries and globally (Pendrill et al., 2019). Thereby, to incorporate this assumption into our model, we have considered the effects of a 5%, 10%, and 20% increase in CSPO costs in Indonesia and the rest of the world. The results are below.

Table 4. Change in market prices, quantities, profit, and demand due to an increase in CSPO for 5%,10%, and 20%.

		Increasing CSPO cost		
		5%	**10%**	**20%**
	Baseline	% Change relative to baseline		
Profit IND	15568.315	-0.004	-0.01	-0.02

		Increasing CSPO cost		
		5%	10%	20%
	Baseline	% Change relative to baseline		
Profit ROW	2684.461	-0.01	-0.02	-0.03
Prices (Euro/MT)				
Palm oil price in IND	1013	-0.0008	-0.0016	-0.0032
Plam oil price in ROW	919.4	-0.0009	-0.0017	-0.0035
Plam oil price in EU	1246	0.01	0.02	0.04
Quantities (million MT)				
Demand palm oil in IND	18.936	0.005	0.005	0.011
Demand palm oil in ROW	4.531	0	0	0
Demand palm oil in EU	4.347	-0.02	-0.05	-0.09
Quantity exported from IND to EU	2.877	-0.03	-0.03	-0.07
Quantity exported from IND to ROW	1.249	0	0	0
Quantity consumed in IND	18.936	0	0	0
Quantity exported from ROW to EU	1.47	-4.29	-0.07	-0.14
Quantity exported from ROW to IND	0.0002	163	460	460
Quantity consumed in ROW	3.282	0	0	0

Source: *GAMS result and own calculation*
IND: Indonesia, ROW: The rest of the world, EU: European Union, MT: Metric Tons, CSPO: Certified Sustainable Palm Oil.

In the second scenario, we observe a slight decrease in demand for palm oil in the EU by 0.01%, 0.02%, and 0.04%, respectively, when we increase the cost of CSPO by 5%, 10%, and 20% in both producer countries. However, the rest of the world shows no change in demand for palm oil, and IND experiences an increase in demand by 0.005% at both levels of increasing the CSPO cost by 5% and 10% and reaching 0.011% in the 20% simulation.

Regarding trade, the exported palm oil from IND and the rest of the world (ROW) to the EU decreases by 0.03% and 0.07%, respectively, in IND and 4.29%, 0.07%, and 0.014% in ROW at the 5%, 10%, and 20% increase of CSPO. The decrease in ROW is quite surprising because the more the CSPO cost increases, the more the trade increases from a 4.29% decrease in 5% to 0.14% in 20% decrease to EU compared to baseline. This happens because it might be more profitable to send premium palm oil to the EU, which we will discuss in the discussion part. Surprisingly, the trade from ROW to IND increases significantly by 163% and 460%. However, there is no change in consumption in IND and ROW, and the exported volume from IND to ROW also does not change.

Regarding price changes, the price of palm oil slightly increases by 0.01%, 0.02%, and 0.04% in the EU. However, the price of palm oil slightly decreases in the rest of the world, i.e., 0.0009%, 0.0017%, and 0.0035%. In IND, the decrease is 0.0008%, 0.0016%, and 0.0032%. Furthermore, the profit margin has slightly decreased after accounting for the increase in the cost of CSPO.

6.1.3 Scenario 3: Increasing the Marginal Cost of Palm Oil

In this scenario, we are exploring the impact of increasing the marginal cost of palm oil by 5% and 10%. The reason behind this increase is that regulations often lead to an increase in the marginal cost of production as stated by Wolfmayr et al., (2024). Therefore, we assume that the EUDR will lead to an increase in the marginal cost of production in the palm oil sector. We will be examining the results of this scenario in both IND and ROW regions. Moreover, we also assume that the EUDR will impact both IND and ROW regions together by increasing their respective marginal costs. By putting this shock in both regions, we can understand the economic impact of this scenario and its environmental consequences.

Table 5. Change in market prices, quantities, profit, and demand due to an increase in marginal cost for 5%, 10%, and 20%.

		Increasing Marginal Cost		
		5%	**10%**	**20%**
	Baseline	% Change relative to baseline		
Profit IND	15568.315	-0.97	-1.95	-3.94
Profit ROW	2684.461	-37.70	-0.97	-2.14
Prices (Euro/MT)				
Palm oil price in IND	1013	0.81	1.59	3.04
Plam oil price in ROW	919.4	1.18	2.31	4.43
Plam oil price in EU	1246	0.87	1.71	3.27
Quantities (million MT)				
Demand palm oil in IND	18.936	-2.18	-4.25	-8.14
Demand palm oil in ROW	4.531	-3.05	-5.94	-11.34
Demand palm oil in EU	4.347	-2.14	-4.19	-8.03
Quantity exported from IND to EU	2.877	-1.67	-3.23	-6.22
Quantity exported from IND to ROW	1.249	-5.68	-11.05	-21.06
Quantity consumed in IND	18.936	-2.18	-4.25	-8.14
Quantity exported from ROW to EU	1.47	-3.13	-6.05	-11.56
Quantity exported from ROW to IND	0.0002	-100	-100	-100
Quantity consumed in ROW	3.282	-2.04	-3.99	-7.65

Source: *GAMS result and own calculation*
IND: Indonesia, ROW: The rest of the world, EU: European Union, MT: Metric Tons.

When the marginal cost of palm oil increases, the supply of palm oil in the trade flow decreases. This leads to a decrease in export volumes from both IND and ROW, resulting in higher palm oil prices in all three markets, and decreasing the profit in the IND and ROW. The biggest decrease in profit happens in ROW reached 37.7% in the case increasing marginal cost for 5%. The largest decrease in exports is from IND to ROW with a decrease of 5.68%, 11.05%, and 21.06% respectively. The biggest effect is on ROW's exports to IND, where there is a decrease of 100%, meaning no exports at all due to the increase in marginal cost. As a result of the increased prices, demand for palm oil decreases in all three markets: by 2.18%, 4.25%, and

8.14% in IND, by 3.05%, 5.94%, and 11.34% in ROW, and in EU by 2.14%, 4.94%, and 8.03 for a 5%, 10%, and 20% decrease, respectively.

6.2 Environment effect in response to EUDR

If the demand for palm oil decreases in the EU, it will have an impact on trade activities and prices. However, this can lead to a decrease in the volume of palm oil exported by Indonesia and the rest of the world. As a result, GHG emissions will also decrease due to transportation activities required to transport palm oil to its final destination, Rotterdam port, Netherlands and Tanjung Pinang port Malaysia, and Surabaya, Indonesia. This calculation of GHG emission was from the production of palm oil to the end of activities exporting to the three markets.

According to a study published by Domnik in 2019, the total carbon emissions produced from transportation activities in palm oil, specifically from CPO, is 5028 kg CO_2-eq./t-km for a journey length of 17252 km from the plantation to Europe and with the capacity of the ships is 1265 tons for domestic water transportation and 15531 tons for international water transportation. We can assume that this value applies to both IND and ROW. In addition, for the IND to ROW, the emission we assume is using 1265 tons of water transportation and the km distance will be 2748 km, then the total emissions from palm oil production to the end consumer in Malaysia port is 4849 kg CO_2-eq./t-km based on the data from Domnik (Domnik et al., 2019) and own calculation. We assume also the total emission IND to ROW is the same as from ROW to IND.

Additionally, it is assumed that the total emissions resulting from the production of palm oil in both IND and ROW countries are the same at 4772 kg CO2-eq./t-km based on the result from Domnik (2019). Finally, when assessing the impact of deforestation, we consider the results from the total production of palm oil under three different scenarios. Here is the result for the total production of palm oil after shocking with three scenarios and followed by the estimation of GHG emissions:

Table 6. Changes in the total production of palm oil in Scenario 1 (decreasing demand in EU)

Total Production (million/MT)	Baseline	Total production in Scenario 1			% Change relative to baseline		
		5%	10%	20%	5%	10%	20%
IND	23.062	23.008	22.954	22.83	-0.0023415	-0.0046830	-0.0100598
ROW	4.7521785	4.738	4.722	4.722	-0.0029836	-0.0063505	-0.0063505

Source: *Own Calculation*

Table 7. Changes in the total production of palm oil in Scenario 2 (Increasing CSPO cost)

Total Production (million/MT)	Baseline	Total production in Scenario 1			% Change relative to baseline		
		5%	10%	20%	5%	10%	20%
IND	23.062	23.061	23.061	23.06	-0.0000434	-0.0000434	-0.0000867

Total Production (million/MT)	Baseline	Total production in Scenario 1			% Change relative to baseline		
		5%	10%	20%	5%	10%	20%
ROW	4.7521785	4.6894689	4.752	4.751	-0.0131960	-0.0000376	-0.0002480

Source: *Own Calculation*

Table 8. Changes in the total production of palm oil in Scenario 3 (Increasing marginal cost)

Total Production (million/MT)	Baseline	Total production in Scenario 1			% Change relative to baseline		
		5%	10%	20%	5%	10%	20%
IND	23.062	22.531	22.026	22.026	-0.0230249	-0.0449224	-0.0449224
ROW	4.7521785	4.639	4.532	4.331	-0.0238161	-0.0463321	-0.0886285

Source: *Own Calculation*

The total production of palm oil is calculated by summing the trade export and domestic consumption. In the context of palm oil production, the anticipated decrease in deforestation, typically associated with reduced production levels, does not directly apply due to the crop's unique characteristics (Oil palm life cycle). Despite observations across three scenarios showing a decline in total production, which might suggest a corresponding reduction in deforestation based on previous studies indicating a link between commodity production and deforestation rates (Lambin & Furumo, 2023; Zhao et al., 2023), the palm oil sector presents a more complex situation which will be discussed in the following section (Discussion section). Nevertheless, the decrease in production of oil palm is expected to lead to a decrease in GHG emissions. Here the expected emission produced from the decreased demand for palm oil in the EU:

Table 9. Emission Calculation in the case of scenario 1 (decreasing demand in EU).

Changes in decreasing demand in the EU	**ΔQuantity in Million MT**			**Emission kg CO_2-eq./t-km**	**Total Emission = ΔQuantity*Emission per t-km**		
	5%	**10%**	**20%**		**5%**	**10%**	**20%**
Quantity exported from IND to EU	-0.072	-0.146	-0.303	5028*	-362.016	-734.088	-1523.48
Quantity exported from IND to ROW	0.003	0.007	0.007	4849*	14.547	33.943	33.943
Quantity exported from ROW to EU	-0.067	-0.069	-0.283	5028*	-336.876	-346.932	-1422.92
Quantity exported from ROW to IND	0.0418215	0.0848215	0.1768215	4849*	202.7925	411.2995	857.4075
Total production in IND	-0.054	-0.108	-0.232	4722*	-254.988	-509.976	-1095.5
Total production in ROW	-0.014178	-0.030179	-0.030179	4722*	-66.9509	-142.503	-142.503
Total emission					-803,4914	-1288,26	-3293,06

Source: *Own Calculation*

* (Domnik et al., 2019)

IND: Indonesia, ROW: The rest of the world, EU: European Union, MT: Metric Tons, CO_2-eq./t-km: carbon dioxide equivalents per ton-kilometer.

According to the findings, implementing EUDR would significantly reduce greenhouse gas (GHG) emissions by 803.4914, 1288.26, and 3292.06 million kg CO_2-eq./t-km in case of a decrease in demand within the EU. The most significant decrease in GHG emissions would occur in the IND to EU and ROW to EU. However, due to an increase in exports from ROW to IND and IND to ROW, GHG emissions would increase by 202.7925 and 411.2995 million kg CO_2-eq./t-km from ROW to IND and IND to ROW, respectively, resulting in an increase of 14.547, 33.943, 33.943, and 33.943 million kg CO_2-eq./t-km in the case of a decrease in EU demand of 5%, 10%, and 20%. Additionally, the most significant reduction in the production of palm oil is in IND, reaching 1095.5 million kg CO2-eq./t-km in the 20% decrease of demand in the EU.

In relation to the effect of EUDR on the cost of CSPO, what would be the environmental impact if the cost for CSPO increased by 5%, 10%, and 20% in the EU market? Due to the decrease in export volume from IND and ROW to the EU, emissions could be reduced. Additionally, the increase in demand from IND and ROW could reduce trade with the EU.

Table 10. Emission Calculation in the case of increasing CSPO cost.

Changes in increasing CSPO cost	**ΔQuantity in Million MT**			**Emission kg CO_2-eq./t-km**	**Total Emission = ΔQuantity*Emission per t-km**		
	5%	**10%**	**20%**		**5%**	**10%**	**20%**
Quantity exported from IND to EU	-0.001	-0.001	-0.002	5028*	-5.028	-5.028	-10.056
Quantity exported from IND to ROW	0	0	0	4849*	0	0	0
Quantity exported from ROW to EU	-0.063	-0.001	-0.002	5028*	-316.764	-5.028	-10.056
Quantity exported from ROW to IND	0.0002904	0.0005311	0.0008215	4849*	1.40815	2.575304	3.983454
Total production in IND	-0.001	-0.001	-0.002	4722*	-4.722	-4.722	-9.444
Total production in ROW	-0.06271	-0.000179	-0.001179	4722*	-296.115	-0.84288	-5.56488
Total emission					-621.221	-13.0456	-31.1374

Source: *Own Calculation*
* (Domnik et al., 2019)
IND: Indonesia, ROW: The rest of the world, EU: European Union, MT: Metric Tons, CO_2-eq./t-km: carbon dioxide equivalents per ton-kilometer, CSPO: Certified Sustainable Palm Oil.

According to the findings, if the demand for sustainable palm oil in the EU drives up the cost of CSPO, it will decrease export activities from IND and ROW to the EU. This reduction in exports, consumption, and production will decrease 621.221, 13.0456, and 31.1374 million CO_2-eq./t-km in GHG emissions, respectively. Surprisingly, ROW will increase its exports to IND, resulting in a significant increase in GHG emissions. The simulation of the 5%, 10%, and 20% shock increase in CSPO revealed that it would have a minor impact on trade between IND and ROW to the EU. This might be because the high prices in the EU market are pushing the producers to export. Additionally, the production cost experiences a reduction in GHG emissions.

Turning to what is the impact of EUDR by increasing the marginal cost in the environment? The assumption is also will decrease the GHG emission since marginal cost will increase the price of palm oil and will lead to a reduction of trade volume. This idea also discussed by Petersen et al., (2024), the concept that low marginal costs result in a reduction of prices in the market, and higher marginal costs lead to an increase in prices.

Table 11. Emission Calculation in the case of increasing Marginal Cost.

Changes in increasing MC	**ΔQuantity in Million MT**			**Emission kg CO_2-eq./t-km**	**Total Emission = ΔQuantity*Emission per t-km**		
	5%	**10%**	**20%**		**5%**	**10%**	**20%**
Quantity exported from IND to EU	-0.048	-0.093	-0.179	5028*	-241.344	-467.604	-900.012
Quantity exported from IND to ROW	-0.071	-0.138	-0.263	4849*	-344.279	-669.162	-1275.29
Quantity exported from ROW to EU	-0.046	-0.089	-0.17	5028*	-231.288	-447.492	-854.76
Quantity exported from ROW to IND	-0.0001785	-0.0001785	-0.0001785	4849*	-0.86555	-0.86555	-0.86555
Total production in IND	-0.531	-1.03	-1.036	4722*	-2507.38	-4891.99	-4891.99
Total production in ROW	-0.1131785	-0.2201785	-0.4211785	4722*	-534.429	-1039.68	-1988.8
Total emission					-3859,587	-7516,8	-9911,72

Source: *Own Calculation*
* (Domnik et al., 2019)
IND: Indonesia, ROW: The rest of the world, EU: European Union, MT: Metric Tons, CO_2-eq./t-km: carbon dioxide equivalents per ton-kilometer, MC: Marginal Cost.

The increase in marginal cost results in a significant reduction of GHG emissions. Table 8 shows that the GHG emissions decreased by 3859.587, 7516.8, and 9911.72 million CO_2-eq./t-km, which is higher than the other scenarios. This is because an increase in marginal cost leads to a reduction in trade volume in the three markets, namely IND, ROW, and the EU, and also decreases palm oil production, leading to reduced GHG emissions.

DISCUSSION

Based on the results of research, it is evident that the demand for palm oil across Indonesia (IND), the rest of the world (ROW), and the European Union (EU) exhibits significant elasticity, indicating a responsive change in demand relative to price variations. This sensitivity to price changes underscores the potential impact of pricing and market fluctuations on palm oil demand. These findings emphasize how the European Union Deforestation-free Regulation (EUDR) could affect the global palm oil market.

7.1 The effect of the EUDR policy in CPO trade flow

There is a question on how the EUDR policy affects trade activity between Indonesia, ROW, and the EU. This question arose because there is no validation yet of trade shifting due to the EUDR policy. Nevertheless, expectations are the same as research from Busch et al., (2022), Köthke et al., (2023), and Partzsch et al., (2023) that there will be a shift after imposing climate regulations to less-regulated countries. Therefore, we found the trade shifting in the case of shocking the demand in the EU, which decreased the demand in the EU. What we found is that the decreasing demand in the EU will decrease the supply of CPO in the EU market, and in response to that, will increase the supply in ROW and IND. This is in line with the research from Wolfmayr et al. (2024) which states that there will be a reduction in total trade after imposing EUDR since a substantial share of deforestation-free products is not allowed to enter the EU Single Market. The export from and to both countries IND and ROW increases, meaning there is trade shift to less-regulated countries. Hence, they export more to the less-regulated countries and decrease the volume of trade to regulated country in line with the assumption. In the scenario of decreasing demand in the EU and increasing CSPO cost, there is a significant increase in the export from ROW to IND. This increase is because the initial value of export from ROW to IND is very low, which is 0.0002 million/MT.

It is surprising that ROW trade decreased despite the increase in CSPO. The research shows that the trade decreased by 4.29% when the cost increased by 5% and decreased to 0.14% when the cost increased by 20% compared to the baseline. This might have occurred because it is more profitable to send premium palm oil to the EU. Bateman's research from 2010) shows that Western consumers are having a willing to pay a higher price for products containing palm oil. Furthermore, the CSPO certificate that producers have will be beneficial for them as it will include them in the global value chain of the EU. Michida's research from 2023 also shows that being a part of the global value chain in Europe or other developed countries is advantageous for producers.

In the scenarios of increasing CSPO and marginal cost, we cannot observe the trade shifting since an increase in the cost of CSPO and marginal cost would result in a decrease in palm oil production. As a result, the supply in all three markets would decrease, leading to price hikes and a decrease in demand as a response to the price. Therefore, based on the results, changing or shocking the cost would affect the availability of palm oil supply in the market, but it would not impact the trade shift. This is consistent with the findings of (Parzianello & Carvalho, 2024) which indicate that an overall increase in costs, leading to a negative impact on exports. Additionally, export activities also have a negative impact in decreasing volume in the market.

Hence, the trade shift will happen in the case of decreasing the demand in EU because IND and ROW will export their palm oil in the less-regulated countries more and will decrease the supply to the EU as the demand decrease in EU. Additionally, if the cost of CSPO and marginal cost increases, it will have a negative impact on trade in all markets.

Nevertheless, this research has limitations in predicting how the palm oil trade may shift in other markets, such as India or China. This is because these countries are also major consumers of palm oil. As the five biggest importers of palm oil in the world is India, China, EU, Pakistan, and USA (CPOPC, 2024a). To gain a more comprehensive understanding of how the EUDR may affect trade shifts from regulated to non-regulated countries, it is still open research to include data from other consumer countries, not just Europe.

7.2 Changes in prices in response to EUDR

The implementation of EUDR has impacted the pricing of palm oil. It is expected that the imposition of EUDR will cause a decrease in CPO price in the EU due to a decrease in demand, while the cost of CSPO and marginal cost will increase the price of CPO. This decrease in demand for CPO in the EU will result in a decrease in its price for all markets, as expected. In the second scenario, the increasing cost of CSPO will lead to a decrease in its price in IND and ROW. However, in the EU, the price will increase because of the demand for sustainable palm oil, so they are willing to accept the high price of palm oil as long as the producers meet their need for CSPO certification. As the study from prices Zhou et al., (2023) and Rougieux & Jonsson (2021), expected that climate policy uncertainty leads to higher oil prices. For the third scenario, an increase in marginal cost in IND and ROW will considerably increase the price of CPO in all markets. It is in line with other study that EUDR will also affect prices from third countries (Wolfmayr et al., 2024). Third countries here are Indonesia (IND) and Malaysia (ROW). And when the price increases, it will lead to decrease of demand. As the price of a commodity increases, the demand for the commodity will generally decrease (Mathias, 2023).

The three scenarios mentioned above will impact both domestic and world prices. In the first scenario, it is projected that the price will decrease due to a decrease in palm oil consumption in the importing country. However, in the case of an increase in the cost of EUDR, the price in the EU market will increase as CSPO certification is required to enter the EU market. This will have a significant impact on the price in the EU. Lastly, if the marginal cost increases, it will lead to an increase in the price of all three markets, and the increase is higher compared to other scenarios. The reason marginal cost is the increase in the cost of inputs needed to produce added output, so if this increases, it will affect the price (Hall, 1986). Overall, the EUDR, through three scenarios, will impact the whole market, and the EU will impact prices more because the price will increase relatively higher than others, except in the decreasing demand, in which the price of the EU decreases. Additionally, the decrease in demand in the EU will also impact the palm oil industry in Indonesia and the rest of the world, as there will be a significant decrease in palm oil prices in the EU, which will also impact the profit of both markets.

This research focuses on reducing the demand for palm oil in the EU, increasing the cost of CSPO, and increasing the marginal cost in IND and ROW. However, we are not testing the impact of increasing the cost of production because it has long-term implications. For now, our research aims to determine the short-term effects of implementing palm oil in the global market. Hence, we simulate the EUDR by increasing the marginal cost. In the practical application of pricing policy in the marginal cost, firm decisions on pricing policy can be taken particularly in the short term (The Institute of Chartered Accountants of India, 2021). Nonetheless, increasing the cost of production would likely result in an increase in the price of palm oil in the market. Therefore, research on this topic remains open.

7.3 Environment effect in response to EUDR

The third research question focuses on the environmental impact of EUDR. The objective is to determine if the policy has led to a reduction in GHG emissions. Additionally, we examine the changes in deforestation levels caused by the expansion of land for palm oil production. Studies show that palm oil production leads to deforestation (Chiriacò et al., 2024; Lambin & Furumo, 2023). Therefore, we analyze the production of palm oil in the three scenarios. We find that the production of palm oil has decreased. However, palm oil trees have a long-term growth cycle, and their production depends on the age of the tree (Zhao et al., 2023). Even if production decreases, it is unclear whether deforestation rates will follow suit, as existing plantations may still be cultivated or expanded to maximize yield over the trees' productive years. Therefore, we focus on the reduction of GHG emissions.

It is expected that the policy has led to a reduction in GHG emissions. From all the simulations conducted, it was found that a decrease in demand in the EU, an increase in CSPO cost, and marginal cost would decrease exports from IND and ROW to the EU. This would lead to a reduction in greenhouse gas emissions. According to Wolfmayr et al. (2024), reducing the use of products that contribute to deforestation can help prevent deforestation and forest degradation. This would also lead to a decrease in greenhouse gas emissions (Cheng et al., 2017; Zhunusova et al., 2022b). On the other hand, an increase in the marginal cost would decrease all trade activities in the three markets, leading to the most significant reduction in greenhouse gas emissions compared to the other scenarios. However, in the first and second simulations, there was an increase in exports from IND to ROW and vice versa, leading to an increase in GHG emissions. But the increase was not as much as the decrease in trade from IND and ROW to EU.

Therefore, the three of scenarios have an impact on the environment, especially can reduce the GHG emissions. Nevertheless, there is a limitation to the result when it comes to assessing whether EUDR can effectively reduce deforestation in the IND and ROW. However, it is possible to determine the level of deforestation after implementing EUDR to assess its effectiveness.

CONCLUSIONS

It is evident that the demand for palm oil across Indonesia (IND), the rest of the world (ROW), and the European Union (EU) exhibits significant elasticity, indicating a responsive change in demand relative to price variations. This research aimed to investigate the impact of EUDR on the palm oil industry's economy and environment. The research focused on three central questions: firstly, how has EUDR affected the trade flow? Secondly, what has been the impact of EUDR on palm oil pricing? And finally, what is the environmental impact of GHG emissions resulting from EUDR? The findings show that the implementation of EUDR has resulted in a shift in trade flow, with a decrease in demand in the EU scenario. However, for other scenarios, it may lead to a negative impact on export. It means there is a decreasing volume of trade in the market. The second question revealed that there were significant changes in pricing in three different scenarios, with the highest increase observed in the marginal cost. Finally, the research found that all of the scenarios resulted in a decrease in GHG emissions, indicating that EUDR positively impacts the environment. However, the correlation between reduced palm oil production and lower deforestation levels remains unclear when addressing deforestation specifically. This uncertainty stems from the reliance on data reflecting production changes without direct evidence of their impact on deforestation rates, making it challenging to determine the regulation's effect in this area conclusively.

The research provides new empirical evidence on how the EUDR affects palm oil trade flows. This research uniquely quantifies the shifts in demand within the EU and identifies potential adverse effects on exports in other scenarios. Such detailed analysis enhances our understanding of global trade dynamics under environmental regulations. By examining the impact of EUDR on commodity pricing, this contribution is critical for policymakers, industry stakeholders, and economists, offering a deeper understanding of the regulatory impact on market prices. The finding that GHG emissions decrease under all scenarios studied provides a robust argument for the EUDR's environmental effectiveness. This research contributes to the ongoing debate regarding the effectiveness of regulatory measures in reducing carbon footprints. Furthermore, it offers quantifiable evidence of the positive environmental impacts of such policies.

RECOMMENDATIONS

This research is focused on the impact of EUDR on the trade flow, pricing changes, and environmental impact. Hence, researching the long-term impact of the EUDR on the palm oil industry, trade dynamics, pricing, and environmental outcomes will also provide insights into the sustainability and effectiveness of the regulation over time. Additionally, a comparative analysis can help identify best practices and lessons learned for designing effective environmental regulations. It is also essential to investigate the socio-economic impacts of the EUDR on communities in palm oil-producing countries, including understanding the regulation's effects on employment, income, and local economies to ensure that environmental policies do not inadvertently exacerbate social inequalities.

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Appendix

Appendix 1. The model GAMS code

```
set i countries / IND, ROW, EU /;

Parameters
a(i) the intercept of demand curve /IND 1390.763561, ROW 1278.488229, EU
1753.650612/
b(i) the slope of demand curve /IND 19.94930292, ROW 79.25753473, EU
116.7902117/
Acapital(i) coefficient /IND 27.54566853, ROW 135.9755321/;

Scalars
tIND_EU      'Transportation Cost from IND to EU'
tIND_ROW     'Transportation Cost from IND to ROW'
CSPO         'CSPO certification cost'
CIND         'Cost of production in IND'
CROW         'Cost of production in ROW'
tROW_EU      'Transportation Cost from ROW to EU'
tROW_IND     'Transportation Cost from ROW to IND'
tROW_ROW     'Transportation Cost from ROW to ROW'
;


*VALUE
CIND = 317.62;
CROW = 323.09;
CSPO = 3.600999479;

*Transportation Cost Calculation
tIND_EU = 271.19;
tIND_ROW = 185.195;
tROW_EU = 424.5373893;
tROW_IND = 366.816439;
tROW_ROW = 13.09677101;

Variables
PEU          'Price and liniear demand function EU'
PROW         'Price and liniear demand function ROW'
PIND         'Price and liniear demand function IND'
QEU          'Demand in EU'
QROW         'Demand in ROW'
QIND         'Demand in IND'
qINDEU       'Quantity exported from IND to EU'
qINDROW      'Quantity exported from IND to ROW'
qINDIND      'Quantity consumed in IND'
qROWEU       'Quantity exported from ROW to EU'
qROWROW      'Quantity consumed in ROW'
qROWIND      'Quantity exported from ROW to IND'
```

```
profIND      'Profit in Indonesia'
profROW      'Profit in Rest of the world (ROW)'
MCIND        'Marginal Cost in IND'
MCROW        'Marginal Cost in ROW'
;

Positive Variables PEU, PROW, PIND, QEU, QROW, QIND, qINDEU, qINDROW, qINDIND,
qROWEU, qROWIND, qROWROW, MCIND, MCROW, tROWEU, tROWIND, tROWROW;

* Set initial values based on empirical data
qINDEU.l  = 2.876688;
qROWEU.l  = 1.47;
qINDROW.l = 1.248651;
qROWROW.l = 3.282;
qINDIND.l = 18.936;
qROWIND.l = 0.0001785;
PEU.l = 1246;
PROW.l = 919.4;
PIND.l = 1013;
QEU.l = 4.346688;
QIND.l = 18.9361785;
QROW.l = 4.530651;
MCIND.l = 635.24;
MCROW.l = 646.18;

Equations
profitIND_eq        'Profit equation for Indonesia'
profitROW_eq        'Profit equation for Rest of the world (ROW)'
PEU_eq              'equation price and linear demand function EU'
PROW_eq             'equation price and linear demand function ROW'
PIND_eq             'equation price and linear demand function IND'
demandEU_eq         'Demand equation for EU'
demandROW_eq        'Demand equation for ROW'
demandIND_eq        'Demand equation for IND'
dProfIND_dqINDEU    'Partial derivative of profIND with respect to qINDEU'
dProfIND_dqINDROW   'Partial derivative of profIND with respect to qINDROW'
dProfIND_dqINDIND   'Partial derivative of profIND with respect to qINDIND'
dProfROW_dqROWEU    'Partial derivative of profIND with respect to qROWEU'
dProfROW_dqROWIND   'Partial derivative of profIND with respect to qROWIND'
dProfROW_dqROWROW   'Partial derivative of profIND with respect to qROWROW'
MCIND_eq            'Equations for Marginal Cost in IND'
MCROW_eq            'Equations for Marginal Cost in ROW'
;

PEU_eq..            PEU =e= a('EU')- b('EU')*QEU;
PROW_eq..           PROW =e= a('ROW')-b('ROW')*QROW;
PIND_eq..           PIND =e= a('IND')-b('IND')*QIND;
demandEU_eq..       QEU =e= qINDEU+qROWEU;
```

```
demandROW_eq..       QROW =e= qINDROW+qROWROW;
demandIND_eq..       QIND =e= qROWIND+qINDIND;
dProfIND_dqINDEU..   -b('EU')*qINDEU + PEU - MCIND - tIND_EU - CSPO =e= 0;
dProfIND_dqINDROW.. -b('ROW')*qINDROW + PROW - MCIND - tIND_ROW =e= 0;
dProfIND_dqINDIND.. -b('IND')*qINDIND + PIND - MCIND =e= 0;
dProfROW_dqROWEU..   -b('EU')*qROWEU + PEU - MCROW - tROW_EU - CSPO =e= 0;
dProfROW_dqROWIND.. -b('IND')*qROWIND + PIND - MCROW - tROW_IND =e= 0;
dProfROW_dqROWROW.. -b('ROW')*qROWROW + PROW - MCROW - tROW_ROW =e= 0;
profitIND_eq..       profIND =e= PEU*qINDEU + PROW*qINDROW + PIND*qINDIND -
CIND*(qINDEU+qINDROW+qINDIND) - tIND_EU*qINDEU - tIND_ROW*qINDROW -
CSPO*qINDEU;
profitROW_eq..       profROW =e= PEU*qROWEU + PIND*qROWIND + PROW*qROWROW -
CROW*(qROWEU+qROWIND+qROWROW) - tROW_EU*qROWEU - tROW_IND*qROWIND -
CSPO*qROWEU;
MCIND_eq..           MCIND =e= Acapital ('IND')*(qINDEU+qINDROW+qINDIND);
MCROW_eq..           MCROW =e= Acapital ('ROW')*(qROWEU+qROWIND+qROWROW);

Model palmOilMarketIND / all /;
Solve palmOilMarketIND using NLP maximizing profIND;

Display
ProfIND.l, ProfROW.l, PIND.l, PEU.l, PROW.l, QIND.l, QEU.l, QROW.l, qINDEU.l,
qINDROW.l, qINDIND.l, qROWEU.l, qROWIND.l, qROWROW.l;
```

Appendix 2. The GAMS results.

Scenario 1: decreasing demand of palm oil in EU.

1. Decreasing demand of palm oil in EU by 5%.

```
PEU_eq..            PEU =e= a('EU')- ((b('EU')*QEU)/0.95);
```

```
109 VARIABLE profIND.L          =    15483.329  Profit in Indonesia
    VARIABLE profROW.L          =     2653.721  Profit in Rest of the world (ROW)
    VARIABLE PIND.L             =     1011.864  Price and liniear demand function IND
    VARIABLE PEU.L              =     1236.241  Price and liniear demand function EU
    VARIABLE PROW.L             =      918.264  Price and liniear demand function ROW
    VARIABLE QIND.L             =       18.993  Demand in IND
    VARIABLE QEU.L              =        4.209  Demand in EU
    VARIABLE QROW.L             =        4.545  Demand in ROW
    VARIABLE qINDEU.L           =        2.805  Quantity exported from IND to EU
    VARIABLE qINDROW.L          =        1.252  Quantity exported from IND to ROW
    VARIABLE qINDIND.L          =       18.951  Quantity consumed in IND
    VARIABLE qROWEU.L           =        1.403  Quantity exported from ROW to EU
    VARIABLE qROWIND.L          =        0.042  Quantity exported from ROW to IND
    VARIABLE qROWROW.L          =        3.293  Quantity consumed in ROW
```

2. Decreasing demand of palm oil in EU by 10%.

```
PEU_eq..            PEU =e= a('EU')- ((b('EU')*QEU)/0.90);
```

```
109 VARIABLE profIND.L          =    15396.707  Profit in Indonesia
    VARIABLE profROW.L          =     2623.029  Profit in Rest of the world (ROW)
    VARIABLE PIND.L             =     1010.684  Price and liniear demand function IND
    VARIABLE PEU.L              =     1226.099  Price and liniear demand function EU
    VARIABLE PROW.L             =      917.084  Price and liniear demand function ROW
    VARIABLE QIND.L             =       19.052  Demand in IND
    VARIABLE QEU.L              =        4.065  Demand in EU
    VARIABLE QROW.L             =        4.560  Demand in ROW
    VARIABLE qINDEU.L           =        2.731  Quantity exported from IND to EU
    VARIABLE qINDROW.L          =        1.256  Quantity exported from IND to ROW
    VARIABLE qINDIND.L          =       18.967  Quantity consumed in IND
    VARIABLE qROWEU.L           =        1.334  Quantity exported from ROW to EU
    VARIABLE qROWIND.L          =        0.085  Quantity exported from ROW to IND
    VARIABLE qROWROW.L          =        3.303  Quantity consumed in ROW
```

3. Decreasing demand of palm oil in EU by 20%.

```
PEU_eq..            PEU =e= a('EU')- ((b('EU')*QEU)/0.80);
```

```
109 VARIABLE profIND.L          =    15217.682  Profit in Indonesia
    VARIABLE profROW.L          =     2562.124  Profit in Rest of the world (ROW)
    VARIABLE PIND.L             =     1008.180  Price and liniear demand function IND
    VARIABLE PEU.L              =     1204.575  Price and liniear demand function EU
    VARIABLE PROW.L             =      914.580  Price and liniear demand function ROW
    VARIABLE QIND.L             =       19.178  Demand in IND
    VARIABLE QEU.L              =        3.761  Demand in EU
    VARIABLE QROW.L             =        4.591  Demand in ROW
    VARIABLE qINDEU.L           =        2.574  Quantity exported from IND to EU
    VARIABLE qINDROW.L          =        1.265  Quantity exported from IND to ROW
    VARIABLE qINDIND.L          =       19.000  Quantity consumed in IND
    VARIABLE qROWEU.L           =        1.187  Quantity exported from ROW to EU
    VARIABLE qROWIND.L          =        0.177  Quantity exported from ROW to IND
    VARIABLE qROWROW.L          =        3.327  Quantity consumed in ROW
```

Scenario 2: increasing CSPO cost.

1. Increasing CSPO cost by 5%.

```
CSPO = 3.600999479*1.05;
```

```
109 VARIABLE profIND.L          =     15567.462  Profit in Indonesia
    VARIABLE profROW.L          =      2684.243  Profit in Rest of the world (ROW)
    VARIABLE PIND.L             =      1012.992  Price and liniear demand function IND
    VARIABLE PEU.L              =      1246.112  Price and liniear demand function EU
    VARIABLE PROW.L             =       919.392  Price and liniear demand function ROW
    VARIABLE QIND.L             =        18.937  Demand in IND
    VARIABLE QEU.L              =         4.346  Demand in EU
    VARIABLE QROW.L             =         4.531  Demand in ROW
    VARIABLE qINDEU.L           =         2.876  Quantity exported from IND to EU
    VARIABLE qINDROW.L          =         1.249  Quantity exported from IND to ROW
    VARIABLE qINDIND.L          =        18.936  Quantity consumed in IND
    VARIABLE qROWEU.L           =         1.470  Quantity exported from ROW to EU
    VARIABLE qROWIND.L          =   4.689365E-4  Quantity exported from ROW to IND
    VARIABLE qROWROW.L          =         3.282  Quantity consumed in ROW
```

2. Increasing CSPO cost by 10%.

```
CSPO = 3.600999479*1.1;
```

```
109 VARIABLE profIND.L          =     15566.868  Profit in Indonesia
    VARIABLE profROW.L          =      2684.025  Profit in Rest of the world (ROW)
    VARIABLE PIND.L             =      1012.984  Price and liniear demand function IND
    VARIABLE PEU.L              =      1246.224  Price and liniear demand function EU
    VARIABLE PROW.L             =       919.384  Price and liniear demand function ROW
    VARIABLE QIND.L             =        18.937  Demand in IND
    VARIABLE QEU.L              =         4.345  Demand in EU
    VARIABLE QROW.L             =         4.531  Demand in ROW
    VARIABLE qINDEU.L           =         2.876  Quantity exported from IND to EU
    VARIABLE qINDROW.L          =         1.249  Quantity exported from IND to ROW
    VARIABLE qINDIND.L          =        18.936  Quantity consumed in IND
    VARIABLE qROWEU.L           =         1.469  Quantity exported from ROW to EU
    VARIABLE qROWIND.L          =         0.001  Quantity exported from ROW to IND
    VARIABLE qROWROW.L          =         3.282  Quantity consumed in ROW
```

3. Increasing CSPO cost by 20%.

```
CSPO = 3.600999479*1.2;
```

```
109 VARIABLE profIND.L          =     15565.680  Profit in Indonesia
    VARIABLE profROW.L          =      2683.590  Profit in Rest of the world (ROW)
    VARIABLE PIND.L             =      1012.968  Price and liniear demand function IND
    VARIABLE PEU.L              =      1246.449  Price and liniear demand function EU
    VARIABLE PROW.L             =       919.368  Price and liniear demand function ROW
    VARIABLE QIND.L             =        18.938  Demand in IND
    VARIABLE QEU.L              =         4.343  Demand in EU
    VARIABLE QROW.L             =         4.531  Demand in ROW
    VARIABLE qINDEU.L           =         2.875  Quantity exported from IND to EU
    VARIABLE qINDROW.L          =         1.249  Quantity exported from IND to ROW
    VARIABLE qINDIND.L          =        18.936  Quantity consumed in IND
    VARIABLE qROWEU.L           =         1.468  Quantity exported from ROW to EU
    VARIABLE qROWIND.L          =         0.001  Quantity exported from ROW to IND
    VARIABLE qROWROW.L          =         3.282  Quantity consumed in ROW
```

Scenario 2: increasing marginal cost in IND and ROW.

1. Increasing marginal cost by 5%.

```
MCIND_eq..          MCIND =e= Acapital ('IND')*(qINDEU+qINDROW+qINDIND)*1.05;
MCROW_eq..          MCROW =e= Acapital ('ROW')*(qROWEU+qROWIND+qROWROW)*1.05;
```

```
109 VARIABLE profIND.L             =     15417.144  Profit in Indonesia
    VARIABLE profROW.L             =      2672.325  Profit in Rest of the world (ROW)
    VARIABLE PIND.L                =      1021.222  Price and liniear demand function IND
    VARIABLE PEU.L                 =      1256.880  Price and liniear demand function EU
    VARIABLE PROW.L                =       930.280  Price and liniear demand function ROW
    VARIABLE QIND.L                =        18.524  Demand in IND
    VARIABLE QEU.L                 =         4.254  Demand in EU
    VARIABLE QROW.L                =         4.393  Demand in ROW
    VARIABLE qINDEU.L              =         2.829  Quantity exported from IND to EU
    VARIABLE qINDROW.L             =         1.178  Quantity exported from IND to ROW
    VARIABLE qINDIND.L             =        18.524  Quantity consumed in IND
    VARIABLE qROWEU.L              =         1.424  Quantity exported from ROW to EU
    VARIABLE qROWIND.L             =         0.000  Quantity exported from ROW to IND
    VARIABLE qROWROW.L             =         3.215  Quantity consumed in ROW
```

2. Increasing marginal cost by 10%.

```
MCIND_eq..          MCIND =e= Acapital ('IND')*(qINDEU+qINDROW+qINDIND)*1.1;
MCROW_eq..          MCROW =e= Acapital ('ROW')*(qROWEU+qROWIND+qROWROW)*1.1;
```

```
109 VARIABLE profIND.L             =     15264.188  Profit in Indonesia
    VARIABLE profROW.L             =      2658.543  Profit in Rest of the world (ROW)
    VARIABLE PIND.L                =      1029.072  Price and liniear demand function IND
    VARIABLE PEU.L                 =      1267.268  Price and liniear demand function EU
    VARIABLE PROW.L                =       940.668  Price and liniear demand function ROW
    VARIABLE QIND.L                =        18.131  Demand in IND
    VARIABLE QEU.L                 =         4.165  Demand in EU
    VARIABLE QROW.L                =         4.262  Demand in ROW
    VARIABLE qINDEU.L              =         2.784  Quantity exported from IND to EU
    VARIABLE qINDROW.L             =         1.111  Quantity exported from IND to ROW
    VARIABLE qINDIND.L             =        18.131  Quantity consumed in IND
    VARIABLE qROWEU.L              =         1.381  Quantity exported from ROW to EU
    VARIABLE qROWIND.L             =         0.000  Quantity exported from ROW to IND
    VARIABLE qROWROW.L             =         3.151  Quantity consumed in ROW
```

3. Increasing marginal cost by 20%.

```
MCIND_eq..          MCIND =e= Acapital ('IND')*(qINDEU+qINDROW+qINDIND)*1.2;
MCROW_eq..          MCROW =e= Acapital ('ROW')*(qROWEU+qROWIND+qROWROW)*1.2;
```

```
109 VARIABLE profIND.L             =     14954.987  Profit in Indonesia
    VARIABLE profROW.L             =      2627.017  Profit in Rest of the world (ROW)
    VARIABLE PIND.L                =      1043.758  Price and liniear demand function IND
    VARIABLE PEU.L                 =      1286.689  Price and liniear demand function EU
    VARIABLE PROW.L                =       960.089  Price and liniear demand function ROW
    VARIABLE QIND.L                =        17.394  Demand in IND
    VARIABLE QEU.L                 =         3.998  Demand in EU
    VARIABLE QROW.L                =         4.017  Demand in ROW
    VARIABLE qINDEU.L              =         2.698  Quantity exported from IND to EU
    VARIABLE qINDROW.L             =         0.986  Quantity exported from IND to ROW
    VARIABLE qINDIND.L             =        17.394  Quantity consumed in IND
    VARIABLE qROWEU.L              =         1.300  Quantity exported from ROW to EU
    VARIABLE qROWIND.L             =         0.000  Quantity exported from ROW to IND
    VARIABLE qROWROW.L             =         3.031  Quantity consumed in ROW
```

Appendix 3. The GAMS results and own calculation.

		Decreasing demand in the EU					
		5%	10%	20%	5%	10%	20%
	Baseline	Change in profits, prices, quantities.			% Change relative to baseline		
Profit IND (π_{IND})	15568.057	15487.329	15396.707	15217.682	-0.52	-1.10	-2.25
Profit ROW (π_{ROW})	2684.461	2653.721	2623.029	2562.124	-1.15	-2.29	-4.56
Prices							
Palm oil price in IND (P_{IND})	1013	1011.864	1010.684	1008.18	-0.11	-0.23	-0.48
Plam oil price in ROW (P_{ROW})	919.4	918.264	917.084	914.58	-0.12	-0.25	-0.52
Plam oil price in EU (P_{EU})	1246	1236.241	1226.099	1204.575	-0.78	-1.60	-3.32
Quantities							
Demand palm oil in IND (Q_{IND})	18.936	18.993	19.052	19.178	0.30	0.61	1.28
Demand palm oil in ROW (Q_{ROW})	4.531	4.545	4.56	4.591	0.31	0.64	1.32
Demand palm oil in EU (Q_{EU})	4.347	4.209	4.065	3.761	-3.17	-6.49	-13.48
Quantity exported from IND to EU (q_{IND}^{EU})	2.877	2.805	2.731	2.574	-2.50	-5.07	-10.53
Quantity exported from IND to ROW (q_{IND}^{ROW})	1.249	1.252	1.256	1.256	0.24	0.56	0.56
Quantity consumed in IND (q_{IND}^{IND})	18.936	18.951	18.967	19	0.08	0.16	0.34
Quantity exported from ROW to EU (q_{ROW}^{EU})	1.47	1.403	1.334	1.187	-4.56	-9.25	-19.25
Quantity exported from ROW to IND (q_{ROW}^{IND})	0.0001785	0.042	0.085	0.177	23429	47519	99059
Quantity consumed in ROW (q_{ROW}^{ROW})	3.282	3.293	3.303	3.327	0.34	0.64	1.37

		Increasing CSPO Cost					
		5%	10%	20%	5%	10%	20%
	Baseline	Change in profits, prices, quantities.			% Change relative to baseline		
Profit IND (π_{IND})	15568.057	15567.462	15566.868	15565.68	-0.004	-0.01	-0.02
Profit ROW (π_{ROW})	2684.461	2684.243	2684.025	2683.59	-0.01	-0.02	-0.03
Prices							
Palm oil price in IND (P_{IND})	1013	1012.992	1012.984	1012.968	-0.0008	-0.0016	-0.0032
Plam oil price in ROW (P_{ROW})	919.4	919.392	919.384	919.368	-0.0009	-0.0017	-0.0035
Plam oil price in EU (P_{EU})	1246	1246.112	1246.224	1246.449	0.01	0.02	0.04

	Baseline	Increasing CSPO Cost 5%	10%	20%	5%	10%	20%
		Change in profits, prices, quantities.			% Change relative to baseline		
Quantities							
Demand palm oil in IND (Q_{IND})	18.936	18.937	18.937	18.938	0.005	0.005	0.011
Demand palm oil in ROW (Q_{ROW})	4.531	4.531	4.531	4.531	0	0	0
Demand palm oil in EU (Q_{EU})	4.347	4.346	4.345	4.343	-0.02	-0.05	-0.09
Quantity exported from IND to EU (q_{IND}^{EU})	2.877	2.876	2.876	2.875	-0.03	-0.03	-0.07
Quantity exported from IND to ROW (q_{IND}^{ROW})	1.249	1.249	1.249	1.249	0	0	0
Quantity consumed in IND (q_{IND}^{IND})	18.936	18.936	18.936	18.936	0	0	0
Quantity exported from ROW to EU (q_{ROW}^{EU})	1.47	1.407	1.469	1.468	-4.29	-0.07	-0.14
Quantity exported from ROW to IND (q_{ROW}^{IND})	0.0001785	0.0004689	0.001	0.001	163	460	460
Quantity consumed in ROW (q_{ROW}^{ROW})	3.282	3.282	3.282	3.282	0	0	0

	Baseline	Increasing Marginal Cost in IND and ROW 5%	10%	20%	5%	10%	20%
		Change in profits, prices, quantities.			% Change relative to baseline		
Profit IND (π_{IND})	15568.057	15417.144	15264.188	14954.987	-0.97	-1.95	-3.94
Profit ROW (π_{ROW})	2684.461	1672.325	2658.543	2627.017	-37.70	-0.97	-2.14
Prices							
Palm oil price in IND (P_{IND})	1013	1021.222	1029.072	1043.758	0.81	1.59	3.04
Plam oil price in ROW (P_{ROW})	919.4	930.28	940.668	960.089	1.18	2.31	4.43
Plam oil price in EU (P_{EU})	1246	1256.88	1267.268	1286.689	0.87	1.71	3.27
Quantities							
Demand palm oil in IND (Q_{IND})	18.936	18.524	18.131	17.394	-2.18	-4.25	-8.14
Demand palm oil in ROW (Q_{ROW})	4.531	4.393	4.262	4.017	-3.05	-5.94	-11.34
Demand palm oil in EU (Q_{EU})	4.347	4.254	4.165	3.998	-2.14	-4.19	-8.03
Quantity exported from IND to EU (q_{IND}^{EU})	2.877	2.829	2.784	2.698	-1.67	-3.23	-6.22
Quantity exported from IND to ROW (q_{IND}^{ROW})	1.249	1.178	1.111	0.986	-5.68	-11.05	-21.06
Quantity consumed in IND (q_{IND}^{IND})	18.936	18.524	18.131	17.394	-2.18	-4.25	-8.14

		Increasing Marginal Cost in IND and ROW					
		5%	10%	20%	5%	10%	20%
	Baseline	Change in profits, prices, quantities.			% Change relative to baseline		
Quantity exported from ROW to EU (q_{ROW}^{EU})	1.47	1.424	1.381	1.3	-3.13	-6.05	-11.56
Quantity exported from ROW to IND (q_{ROW}^{IND})	0.0001785	0	0	0	-100	-100	-100
Quantity consumed in ROW (q_{ROW}^{ROW})	3.282	3.215	3.151	3.031	-2.04	-3.99	-7.65