**DRAFT: NOT FOR PUBLICATION**

# The European Union deforestation-free policy and the potential impacts on the Brazilian economy: the soy supply chain case


## ABSTRACT

The European Union approved a pioneering law aimed at ensuring deforestation-free supply chains for various commodities. This paper explores the implications of this policy on the Brazilian soy supply chain, examining contrasting perspectives from industry associations and environmental organizations. The objective is to estimate the economic impact of the European Union Deforestation-Free Regulation (EUDR), utilizing a multiregional CGE model to analyze variations across Brazilian regions and changes in land use. A dynamic model was used to simulate the impact on the Brazilian economy until 2030. Without EUDR's risk classification countries list, three policy scenarios with possible classifications are run. These scenarios compare with the baseline projection, reflecting historical trends. Policy Scenario 1 (1AMZN) increases costs just in the regions in the Amazon biome, Scenario 2 (2AMZCER) similar to one but includes regions in Amazon plus Cerrado biomes, and Scenario 3 (3ALL) for all regions exporting to the European Union. The goal is to highlight EUDR's impact on Brazilian economic growth under different risk classifications. The results showed a multifaceted impact of on the Brazilian economy and emissions. Key findings include a potential reduction in deforestation, aligning with the regulation's objectives, but with a minor negative impact on national GDP and currency devaluation. Notably, middle-class households may face reduced consumption capacity due to wage reductions, raising concerns about their overall quality of life. The research indicates a shift in cultivation towards alternative crops, such as coffee, corn, orange, rice, and wheat, as viable substitutes for soybean production, but does not completely offset the reduction in soybeans. Regionally, the impact varies, with Mato Grosso and Rondonia expected to be most negatively affected aggravating regional economic inequality. While emissions are projected to decrease in most regions, Mato Grosso, Rondonia, MaToPi, and ParaAP may experience an increase due to pasture emissions from ranching as an alternative to soy production. Economic downturns are predicted for MaToPi and Bahia, areas with increased agricultural production and substantial forest land. The impact increased progressively from 1AMZN, to 2AMZCER, and in 3ALL, however scenarios 2AMZCER and 3ALL had similar values with nuanced differences that indicate the inclusion of Cerrado biome would have the same effect as classifying the whole country as high-risk.



Keywords: economy; land use; CGE; deforestation; EUDR; soy.

# 1. INTRODUCTION

The European Union (EU) approved a law in 2023 to ensure that the supply chains of various commodities and derived products are free from deforestation (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2023). The regulation aims to: (i) combat deforestation (regardless of whether it is legal or illegal); (ii) establish strict traceability requirements, linking commodities to the agricultural lands where they were produced; and (iii) establish a benchmark system which creates a risk classification for producing countries. The new regulation was finalized and published in June 2023 and companies are expected to comply and undergo rigorous audits before placing their products on the European market when the restrictions come into effect in December 2024. Intense debate preceded this regulation, with some unresolved issues in these negotiations still to be decided in further reviews, such as the inclusion of other biomes; the inclusion of the financial sector; the expansion of the list of covered commodities and derived products; and the impacts on indigenous communities.

Three major European industry associations concerning these commodities, namely COCERAL (European Association of Cereal Trade, Oilseed, Pulses, Animal Feed, Olive Oil, Oils, and Fats), FEDIOL (European Vegetable Oil and Protein Industry Association), and FEFAC (European Feed Manufacturers' Federation), have jointly called on the European Council and European Parliament to prevent any negative impact on supply chains caused by the new regulation, warning of a risk of limiting available supplies and its effect on consumer prices. A particular concern involves soybeans and soybean meal, as these associations argue that most currently imported volumes will not be able to comply with the new regulation, even if they are not sourced from deforested areas. This is because on top of geolocation data and due diligence statements, the law also requires a system that physically separates compliant soy from non-compliant soy throughout the entire supply chain, requiring high expenditures on new or adapted infrastructure to duplicate supply chains. These associations project that segregated chains for deforestation-free products will only be observed at smaller ports currently used for certain market niches, such as non-GMO soy. This implies efficiency losses in the shared logistics infrastructure of larger ports and significant cost increases for soy and soy-derived products.

In contrast, 34 institutes and NGOs including IMAFLORA (Climate Observatory and the Institute for Forest and Agricultural Certification and Management) oppose this disruptive vision of agribusiness, arguing that these requirements are essential to ensure the elimination of deforestation, land conversion, and human rights abuses in commodity supply chains. They also note that evidence of transparency and traceability to the origin are perfectly possible and financially feasible, as exemplified by the Brazilian Amazon Soy Moratorium of 2008. The Amazon Soy Moratorium prohibited the acquisition of soy produced in deforested areas in the Amazon biome. Now 15 years since the original agreement, 98% of the soy cultivation in the biome is in compliant areas, and 95% of associated companies have complied without any violations. In a report IMAFLORA highlights that the adaptation of company management systems and technological investment to increase efficiency were instrumental in filtering out improper suppliers. Although Brazil has succeeded and gained experience in using these control systems, the new regulations are a forceful change for a country that is the main exporter of soy to the EU with 39% share of the 11,133 EUR million import value, and it remains to be seen how the agricultural industry will adapt, and whether the new regulations will ultimately result in land use changes that improve or worsen deforestation.

The overall objective of this work is to estimate the expected impact on the Brazilian economy that the European Union's new legislation will have on the Brazilian soy supply chain, as well as any resulting changes in land use. As various regions of Brazil produce soy products at higher rates than others, and the amount of soy divided between domestic consumption and exports differs as well, the economic impacts will not be uniform. Thus, a multiregional CGE (Computable General Equilibrium) model will be used to analyze the regional impacts to various shocks over time, both in an aggregated and regional manner. What is certain is that the increased scrutiny of the supply chain will increase costs, and our model will run three different scenarios considering increasing restrictions (and costs) for export into the EU.

The specific objectives of this work include:

- Investigating the details of European legislation (how it intends to trace back the soy to the origin, how will categorize risk, oversee, and achieve its objectives);
- Determining the potential increase in the cost per ton of soy due to legislation for each region;
- Determining whether there will be a reduction, and to what extent, in exports of soy products from Brazil;
- Analyzing how it will affect the Brazilian regional economy, and which states and industries will be most impacted economically;
- Analyzing changes in land use patterns, whether soy farms will transition to other crops or agricultural activities, and which ones, and whether land use changes through deforestation will decrease or increase due to the application of the new regulation;
- Estimating any increase or reduction in carbon emissions, an important factor in justifying the implementation of the EUDR.

This research also aims to fill a noteworthy gap in the existing literature, which has very limited studies regarding economic analysis of deforestation-free regulations on supply chains.

## 2. EXAMINING EUDR: UNPACKING DUE DILIGENCE SYSTEM REQUIREMENTS

The new EU legislation on the trade of deforestation-free commodities (EUDR) (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2023) requires exporting companies to ensure traceability and physical segregation of the product throughout the entire supply chain, from soybean harvesting to loading onto ships. The legislation compels companies to implement due diligence systems that must (i) trace the origin of soybeans, (ii) do data analysis, and (iii) perform risk mitigation. Although the latter two points will only be required from importers and exporters trading products from a "high-risk" country or region according to the EU benchmark system.

To classify producing countries, the EU authorities will monitor deforestation and forest degradation rates, expansion of agricultural land for relevant commodities, production trends for commodities and relevant products, among other factors. They will maintain an updated classification list for countries or their regions, categorizing them as low or high risk. For Brazil, 92% of soy produced in the Amazon biome is grown in at-risk municipalities and thus will likely be included as “high-risk”(BELLFIELD et al., 2023). The closing decisions on risk factor have not been disclosed yet, nor whether the risk factor would apply to the entire country, or only regions classified as forest ecosystems. The question of the inclusion of non-forest ecosystems has not yet been resolved. A major part of the Cerrado biome, the Pantanal and Pampas biomes are non-forest ecosystems, and their risk factors are scheduled to be disclosed between July 2024, and June 2025.

Commodity market operators, specifically companies exporting soybeans and soybean meal, will be monitored, and held accountable by enforcement authorities if they fail to meet the requirements of the EUDR. In practical terms, this entails providing the necessary commercial documentation and submitting a Declaration confirming that they have successfully exercised due diligence and that the products they place on the market comply with the rules described in the EUDR. This document should include monitoring information such as the geographical coordinates of the farm or plantation where the commodities were grown, to ensure that (i) these commodities and products were not produced on deforested or degraded lands after December 31, 2020, and (ii) they were produced in accordance with the laws of the country of production.

Companies operating in "low risk" areas will only need to submit this Declaration document. Operators located in "high-risk" areas however will need to submit the Declaration and provide extra data analysis, assessing the potential risks in their supply chain. Additionally, appropriate, and proportional mitigation measures, such as replacing suppliers, may be required. Importers of commodities may face penalties if they engage in irregular operations. These penalties may include fines, product seizures, loss of revenue, suspension, or prohibition of relevant economic activities, and even exclusion from government procurement processes for operators and traders who violate the Regulation.

Attached to EUDR, the European Commission released the Impact Assessment that underlies the regulation (EUROPEAN COMMISSION, 2021a). The purpose of the report was to determine the most efficient way of obtaining their goals regarding deforestation targets and to ascertain the gains and losses expected for different actors along the supply chain. The document identified cattle, wood, palm oil, soy, cocoa, and coffee as the most relevant commodities that impact global deforestation and forest degradation. It also expects an increased demand for these commodities and derived products from countries or regions considered “low risk,” as operators that source from such locations would have reduced costs compared to operators from “high-risk” places. So, Brazil which is the main exporter of soy might fall to a lower position if classified as “high-risk” and other big exporters like the US were classified as “low risk”. These changes will result in a minimal increase in product prices for European consumers as the additional costs imposed on producers tend to be passed on down along the supply chain.

The Impact Assessment notes that estimations of investment and recurring costs of due diligence systems presents uncertainties and limitations, which depend on the current size and complexity of the supply chain in the producing country. There are one-off costs to launch the necessary systems and staff needed to perform the analysis, and recurring costs to maintain the system year over year. For reference the Impact Assessment relies on the EUTR due diligence systems, a similar legislation that has been in place for over 10 years for timber and timber products. Under the EUTR, the one-off costs of setting up the due diligence system were between €5,000-€90,000 per operator. And the recurrent costs of the system were estimated between the range of 0.29% to 4.3% of the value of the imports. The document applies these estimates to the recurrent costs of due diligence for the soy supply chain which would fall between the range of 32 to 479 million EUR, based on soy’s 5-year (2015-2019) average import value. It should be noted that the Assessment applies the same range for every commodity considered, and that some supply chains may be more complex than the timber supply chain. Currently only 17% of soybean companies have a comprehensive risk assessment and only 10% have implemented high levels of traceability to municipality level (CDP, 2021).

Operators will have to engage in changing supply chain operating procedures, establish essential IT systems for data collection and verification. Audits, a key part of the process, will involve fees paid to third parties for comprehensive assessments. A relevant additional cost not mentioned in the Impact Assessment is the impact of physical segregation, namely the isolating or reduplicating of transportation and storage components in the supply chain for deforestation-free soy, which is an important decision factor for operators at sourcing countries like Brazil and will be analyzed closer in the next section. Figure 1 demonstrates the controls required in each link of the soy supply chain. Failure to meet either of these requirements or to submit the Declaration will result in a prohibition on placing these products on the EU market.

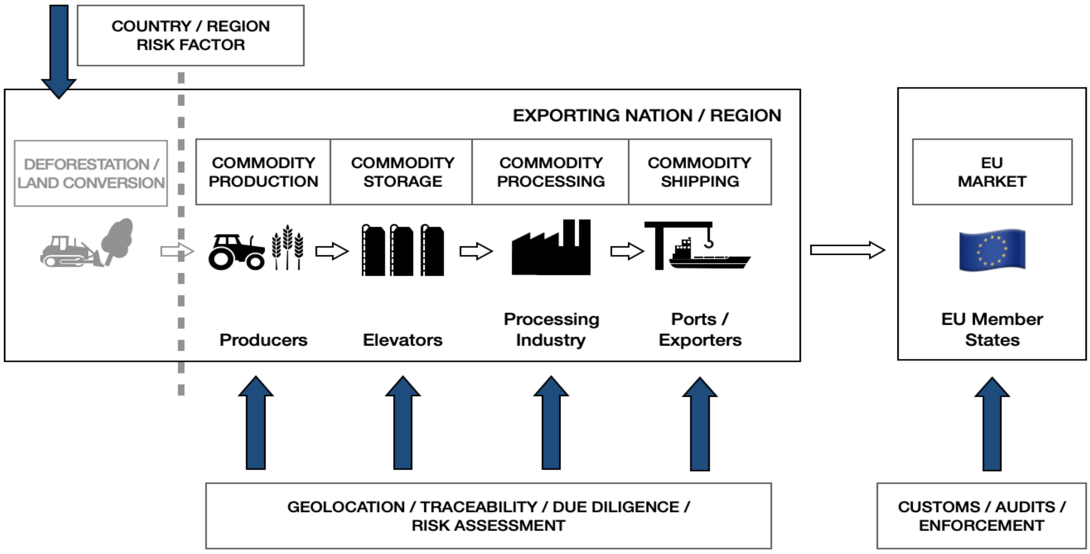


Figure. 1 The scope of the EUDR in placing controls aimed at eliminating commodities produced on deforested land from reaching the EU market. Source: Elaborated by the author

The traceability requirements start with demanding the geographical coordinates of the land plot or farm where the commodities or derived products were produced. Satellite imagery is used to verify whether the land plot or farm were recently forests. Ground and satellite monitoring is a field-tested combination that has proven to be capable of containing deforestation in a given area while making fraud in supply chains more complicated and easily detectable. The EU has developed its own positioning, navigation, and timing satellite system (PNT) (EGNOS/Galileo) and its own Earth observation and monitoring system (Copernicus). Both EGNOS/Galileo and Copernicus offer advanced services to public and private users. Thus, the satellite imagery and resulting positioning obtained using EGNOS/Galileo and Copernicus can be part of the information used for compliance checks (EUROPEAN COMMISSION, 2021b). Any commodity production geolocated to land classified as forest after the cut-off date of December 31, 2020, would no longer be permitted access to the European market.

In Brazil, when registering a property in the Rural Environmental Registry (CAR), the owner or possessor is required to provide: (1) their identification; (2) proof of ownership or possession; and (3) identification of the property through a map and descriptive report containing geographical coordinates, and, if applicable, indicating the location of protected areas (remaining native vegetation, Areas of Permanent Preservation, Restricted Use Areas, consolidated areas, and Legal Reserves) (MINISTÉRIO DO MEIO AMBIENTE E MUDANÇA DO CLIMA, 2023). Therefore, Brazilian farmers already provide this information to the Brazilian authorities to regularize their commercialization, so it isn't a big lift compared to other nations which may not have such a system in place. Geolocating the land plot becomes more critical when auditing deforestation-free soy products. Unlike the straightforward verification process between GMO and non-GMO soybeans, confirming deforestation-free status isn't achievable through laboratory tests (Lippert, 2009). Thus, it becomes essential to track the product seamlessly along the supply chain to guarantee its authenticity, quality, and safety, thereby ensuring deforestation-free production.

Traceability systems along the supply chain are often referred to as Chain of Custody (CC) systems (ISEAL ALLIANCE, 2016) and can be combined with certification systems that classifies a product according to their source and their chain of custody. In the figure below, we have four different forms of CC systems for agricultural supply chains: identity preservation, segregation, mass balance, and book and claim (HINKES; PETER, 2020; ISEAL ALLIANCE, 2016). Soy certified as identity preserved has the highest level of traceability, as each certified source is kept physically separate from other sources, especially non-certified soy. Segregation allows for the mixing of certified soy from different certified sources yet keeps the certified soy physically separate from non-certified sources. Under the mass balance approach, the mixing of certified and non-certified soy is allowed. The respective quantities must be controlled throughout the chain, so that the input-output ratio remains constant. Different forms of mass balance are possible depending on the level at which the mixing of certified and non-certified material occurs (e.g., batch level, site level, group level). Book and claim are an approach that facilitates the trading of certificates independently from certified products (HINKES; PETER, 2020). The EUDR does not specifically name which form of custody chain companies will need to follow, however industrial associations and NGOs have interpreted that the requirements fit a segregation chain of custody while the production sector have argued for the mass balance method instead.

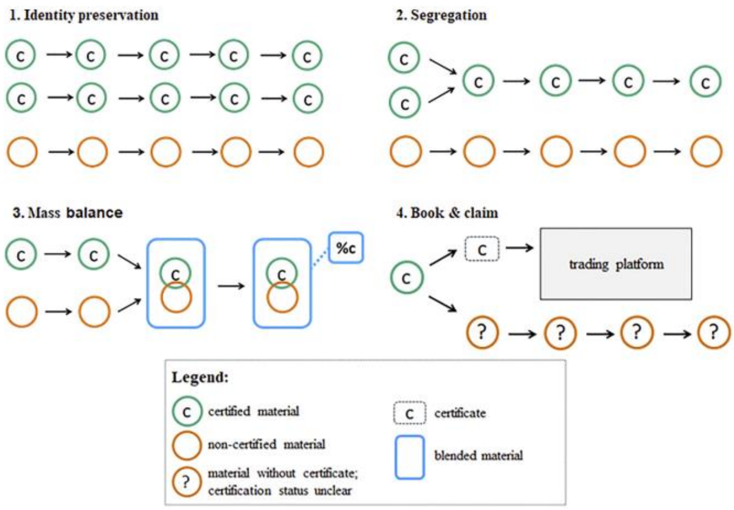


Figure 2 – Common types of custody chain systems
Source: Hinkes e Peter (2020)

Brazil currently exhibits a notably high adoption rate of certifications compared to other South American soybean producers. This widespread certification, coupled with the sustained production of non-genetically modified soybeans, has afforded Brazil a competitive edge in trading with European countries (GARRETT; RUEDA; LAMBIN, 2013). Notably, a report from FEFAC indicates that approximately 25% of soy from EU27+ countries was certified deforestation-free in 2020 (IDH, 2022). The transition to 100% deforestation-free soy as envisioned by the EUDR however represents a substantial leap in compliance and the need for more stringent chains of custody than mere certification. A significant restructuring of supply chain management for Brazilian exporters will be necessary, and businesses must prepare for increased scrutiny and the potential cost implications of being classified as a “high risk” region. Nevertheless, by embracing these changes, companies can not only secure access to the European market but also contribute to global sustainability efforts.

## 3. IMPLICATIONS OF SEGREGATION IN THE BRAZILIAN SOY SUPPLY CHAIN

Among the various commodities listed in the EUDR legislation, soy stands out due to its extensive cultivation in Brazil, considerable value, intricate supply chain dynamics, and its importance to Brazil / EU trade. Soy is globally traded and is the world’s largest source of animal protein feed and the second largest source of vegetable oil. The global soybean market attained a value of 151.4 billion USD in 2022 (“Soybeans | Engage the Chain”). The EU-27 is the second-largest importer of soybean meal, and soy products were determined to be one of the two largest contributors to EU-embodied deforestation from the period 2008-2017, responsible for 32.83% (the other being coffee at 33.95%) (IDH, 2022; “Soybean Market Size, Share Growth, Trends 2023-2028”,). Brazil is still the leading source of soy products to the EU, responsible for 39% of EU imports from 2015-2019 (EUROPEAN COMMISSION, 2021a). Soy was chosen as the focal point of this study both for its relevance to EU commodity imports and its relevance to sustainability efforts. The objective of this paper is to quantify the economic and environmental impacts that will occur under the EUDR and to help both industry and sustainability groups better understand the potential outcomes of this regulation. Segregation will involve a series of various actors along the supply chain, as described below.

### *3.1. Producers*

The producer is the first link in the soybean supply chain. Farmers purchase seeds from a seed company and sell their crop to a warehouse after harvest. Once the soybeans are mature, they undergo several operations aimed at preserving the original quality of the grains. Several chemical compounds, including fungicides and herbicides, are used in the treatment of soybean seeds to inhibit damage to the crop. After harvest, soybeans can be stored on the farm before being sold or directly sent to silos and warehouses (THAKUR; DONNELLY, 2010).

### *3.2. Elevators*

This is a very important link between the producer and the processing industry. Because they buy soybeans from farmers, store them, and mix them before selling them to processors. The received soybeans are sampled and classified based on moisture content, test weight, foreign material, and damaged material. Farmers are paid according to the quality grade. The grains are then transported to storage silos before being shipped to customers. A storage silo can contain soybeans from multiple producers. Batches received from farmers are mixed before shipment to meet the buyer's quality specifications. A batch sent to the processor may contain soybeans from many sources that may end up in the finished product (THAKUR; DONNELLY, 2010). The EUDR will require Elevators to avoid mixing recently deforested areas and non-deforested areas. It will be necessary to assign some silos for each type first. When the facility only has a few grain storage silos, it is possible to segregate one crop from the others but not necessarily allowing the segregation of different qualities of a particular crop. Not all elevators are able to segregate products within a facility (at least without additional investment) (BULLOCK; DESQUILBET, 2002)

### *3.3. Processing industry*

The processing industry is responsible for crushing soybeans, resulting in soybean oil and meal through solvent extraction. While soybean oil is intended for human consumption, the meal is used in animal feed production. The arrival of soybeans at the factory occurs by trucks, where they are then received, sampled, and analyzed for moisture, weight, foreign and damaged material, and stored in silos until the appropriate time for processing. Before this stage, soybeans go through a cleaning process to remove any impurities and loose shells (THAKUR; DONNELLY, 2010). Devoting specific equipment for processing soybeans from recently non-deforested areas implies the loss of efficiency and additional costs for processors (BULLOCK; DESQUILBET, 2002) as it can reduce the available soy to process and impact the demand for silos to segregate.

### *3.4. Port terminals*

The export storages have a physical layout similar to rural elevators, but on a much larger scale. An important difference lies in the amount of port terminal turnover and less in its static capacity. Private or public, they receive loads through railroads, highways, and waterways, store them, and unload them onto bulk carriers – ocean vessels specially designed for this type of transportation. In addition to storage and loading, these storages also offer "blending" services. When loading a bulk carrier, port terminals often combine products from different batches to meet the specifications detailed in a contract with a customer, such as moisture percentage and presence of impurities (Contracts, as a rule, stipulate a price based on compliance with the quality standard with discounts applied for defects). This additional service is a significant source of profit for these port terminals and will need to be revisited considering EUDR's requirements (BULLOCK; DESQUILBET, 2002; THAKUR; DONNELLY, 2010).

The current complexities within the soy supply chain, involving producers, elevators, processing industries, and port terminals are all predicated on permitting and even encouraging the mixture or blending of soy products from various sources, separated more by quality than origin. The establishment of new, segregated deforestation-free supply chains will require careful consideration and significant investments to align with the EUDR requirements.

## 4. INVESTIGATING THE EFFECTS OF EUDR ON BRAZILIAN SOY PRODUCTION

The explicit effect of the EUDR is the increase of costs to implement the due diligence system and the physical segregation of products. The impact assessment gave an estimate of the due diligence cost, but overlooked the segregation cost component, necessitating a search in the available literature. The costs of segregation are incurred throughout the agri-food supply chain to maintain commodities and their derivatives separate (SOUSA, 2020). Suppliers of segregated products can cover these additional expenses by receiving price premiums from buyers (KALAITZANDONAKES; LUSK; MAGNIER, 2018). In the soy supply chain, farmers generally are willing to adopt segregation production practices only if the premiums cover the increased production costs associated. Any difference between the premium and the on-farm costs is profit for the farmer. Therefore, the actors across the soy supply chain have an expectation of a premium price from the European Union, which has been signaled in the Impact Assessment but which the EUDR has not detailed so far.

Segregating products involves various parameters that generates cost. For example, segregation for elevators should include the costs of underutilized capacity, costs of managing new grain flows, costs of extra grain handling, costs of reducing blending capacity, hiring costs, and indirect costs of waiting for compliance verification. The farmers will only adopt these practices if the premiums sufficiently cover the additional costs, indicating that they are reassured about the potential profitability of such practices. Renegotiating contracts due to segregation can take various forms, depending on the characteristics of the transaction and attributes of the product to be segregated (SOUSA, 2020). The risks of non-compliant shipments are lower if the seller commits to segregation practices in a contract. Early contracting also allows the buyer to plan volumes and flows, helping mitigate any information asymmetry.

Facilities with only one grain path would have to dedicate the entire facility to one type of product, never both. Consequently, farmers would have to travel a bit farther, on average, to deliver their grains to a handler. By signing such contracts, farmers and handlers agree on the number of harvested acres that will be delivered to the elevator shortly after harvest and how many acres will be stored on the farm and brought in later specified by the grain handler. This contracting allows grain handlers to plan when they will receive deliveries in the months following the harvest (KALAITZANDONAKES; LUSK; MAGNIER, 2018).

Once concern is that soy imports destined for the EU will instead be diverted to other non-participating countries. A study on the impact of EUTR (which is the predecessor to the EUDR) showed the market for wood products from suspicious sources shifted to unregulated markets experiencing a rapid increase in demand (ROE, 2015). Sun and Bogdanski (2017) demonstrated that policies with increased transaction costs on exports from high-risk producing countries involved in illegal logging, benefit non-participating importing countries, and give them no incentive to join. According to Bastos Lima (2024), EU policymakers are aware of their limitations due to the risk of leakage, and therefore hope to bring other major importing markets – such as China – on board. However, it is unlikely that China will adopt regulations based on zero deforestation in the foreseeable future, over fears of hampering its own food security by impacting agricultural commodity prices or possibly disrupting supplies, coupled with a default policy attitude of non-interference in the domestic decisions of its trade partners, preventing China from enacting strict demand-side measures.

Other raised concerns are the unintended consequences for vulnerable groups in producing countries, such as smallholders, Indigenous people, and local communities. These unintended consequences could include the exclusion of smallholders, Indigenous peoples, and local communities from high-value supply chains of commodities, insufficient price premiums or their unequal distribution to help cover the costs of complying with the regulations, increased risks of land conflicts between large-scale and small-scale agriculture, pushing smallholders to marginal lands, and even exacerbate human rights risks associated with large-scale commodity production (Zhunusova, 2022).

The cost increases for exporting soy products under the EUDR are unknown at this time, and one of the objectives of this paper is to estimate their value, which will be calculated in the next section. If the costs can be balanced out with price premiums and guaranteed by contractual agreements in advance than the expectation is that soy exports from Brazil to the EU will be minimally affected. However, if the Brazilian soy supply chain is expected to absorb the costs unilaterally, than there is a greater chance of a reduction in total soy exports as well as a shift of soy exports towards unregulated countries. A dynamic model will be used to track the changes in soy production, soy exports, and changes across other industries and regions caused by the EUDR regulations, and the implementation of this model and its results will be discussed in the following sections.

# 5. METHODOLOGY

A Computable General Equilibrium model known as TERM-BR was used to calculate the economic impacts of the EUDR on the Brazilian supply chain, and the Brazilian economy both at the national and regional level. Environmental policies have given rise to increased adoption of Computable General Equilibrium (CGE) modeling, serving as a pivotal link between economic theory and practical policy research. Single-country CGE models, among many other things, have been used for evaluation of the efficiency of emission taxes and other environmental policy instruments (BERGMAN, 2005).

TERM, also known as The Enormous Regional Model, is a multiregional CGE model that focuses on analyzing the regional impacts across many sectors for various induced shocks. This model treats each region within a single country as a separate economy, allowing for detailed examination of region-specific characteristic, and is particularly suitable for large countries with numerous states or provinces, such as the United States or China. By utilizing TERM, researchers can gain valuable insights into the economic dynamics and regional effects in a specific country's economy (HORRIDGE, 2012). TERM-BR is a single-country version that incorporates annual recursive dynamics and offers a detailed bottom-up representation for 27 independent models which represent the 27 regions in Brazil (26 states plus the Federal District). The dynamic version is composed of 122 sectors (industries), 122 commodities and 27 regions, interconnected through the goods markets by an interregional trade matrix, and through the market of primary factors of production, with labor and capital treated as movable between activities and regions. TERM-BR also has a module that tracks land use change (LUC) in each state. The LUC module relies on a transition matrix, which illustrates the changes in land use among different categories, namely crops, pastures, forestry, and natural forests, across the specified years. This transition matrix is able to project the deforestation rate or the increase in total land supply (FERREIRA FILHO, et al., 2015).

## *5.1. Database*

In regional CGE modeling, the quality of the output is highly dependent on the quality of the input and a significant challenge arises from the fact that the data requirements often surpass what is readily available. This poses a limitation in accurately representing the complexities of regional economies. Additionally, regional input-output tables, which serve as crucial inputs for these models, may contain deficiencies. These deficiencies can range from a lack of detailed sectoral distinctions, incomplete or inconsistent data, or a general lack of granularity (HORRIDGE, 2012). To address these challenges and construct the necessary database for this study, the primary input is the input-output matrix based on the year 2015 created and released by the Brazilian Institute of Geography and Statistics (IBGE). This matrix provides valuable insights into the interdependencies of sectors within the economy. The model was supplemented with additional data from other databases such as the National Household Sample Survey (PNAD/IBGE), Family Budget Survey (POF/IBGE), population projections from IBGE, and the Municipal Agricultural Production data (PAM/IBGE).

To ensure the model's continued relevance and accuracy, the database was updated with historical economic data up to the year 2022 to indicate the current economic landscape and then projections were compiled yearly up to the year 2030. Various macroeconomic variables, including real GDP, household and government consumption, exports, and investments, are employed to capture the dynamics of the regional economy. In addition, international commodity prices play a crucial role in determining quantities and price changes and are sourced from reputable institutions such as the International Monetary Fund (IMF), Food and Agriculture Organization (FAO), and the

World Bank. When aggregating the regional data, careful consideration is given to the importance of agricultural activities in each region. This ensures that the representation adequately reflects the regional differences and their impact on the overall model outcomes. Moreover, the TERM-BR model incorporates transition matrices between crop areas, pastures, and forestry from the LUC module. These matrices determine the growth in agricultural land area on a consistent basis, ensuring that the increases respect the availability carried forward from the previous year.

### *5.2. Aggregating the TERM-BR model*

For this study concerning soy production in Brazil, the model was aggregated to incorporate 14 regions (see Figure 3), 39 commodities and 39 sectors (industries). The model distinguishes 3 types of production factors (labor, capital, and land), as well as 10 distinct labor occupations per region with some substitution. Additionally, the model accounts for two types of margins, namely trade and transport (DOS SANTOS; DE OLIVEIRA; FILHO, 2021). The model was used to construct a base forecast for the future state of the economy to which different policy scenarios can be compared. The new scenarios differ from the base only via shocks on policy variables, which generate deviations from the base that can be interpreted as the effect of the policy change. Therefore, it is important to extensively estimate the shock to properly determine the effect of changes due to policy, which the next section details.


Figure 3 – Map of grouped Regions used in the model
Source: Elaborated by the author.

### *5.3. Shock estimation*

Two components are needed to determine the adequate shock to the Brazilian economy for a cost increase for the export of soy products to the EU. The first component is an accurate assessment of the increase in cost to comply with the EUDR's regulations, and the second component is calculating the share of soy exports from each state heading to the EU, as soy used for national consumption or for export to non-EU countries, i.e. China, would not be affected. The cost increase was calculated from a test run by Pires[1] in partnership with Menthonnex[2], which was designed to ensure traceability and transparency. The test run consisted of filling a ship at the Port of Santos with

1 Pires, Bernardo. (Abiove). Information received by email. 2023.

2 Menthonnex, Daphné. (Earthworm Foundation). Information received by email.2023.

segregated and non-deforested soy produced in the state of Mato Grosso and processed into soybean meal. The soy was produced on farms which were identified as deforestation-free by PRODES/INPE mapping data from January 2021 onward. The segregation, tracking, and due diligence procedures resulted in an additional cost of €30/ton of product. The risk assessment costs associated for "high-risk" regions was estimated to add an additional €2/ton by the Earthworm Foundation. Other possible factors could influence export costs, but the increased costs of €32/ton is a reasonable representation of the change in price for exporting to the EU under the EUDR, and based on the current price of soybeans represents a price increase of 6% per ton of the CBOT from April 2022 to April 2023.

The 6% increase is the maximum incremental cost provided that all soy products were exported to the EU. To determine the actual share of soy product sent to the EU by each region data was obtained from Trase (TRANSPARENCY FOR SUSTAINABLE ECONOMIES (TRASE), 2018). Trase is an organization that has developed a database specifically designed to track the soybean supply chain in Brazil and evaluate its links to deforestation. It integrates data from a variety of sources like Comex Stat to access commercial records per vessel, from ABIOVE, CONAB, and CGC MAPA for information on crushing and storage facilities, locations, capacities, export authorizations, and transportation costs, as well as data from soybean-producing municipalities obtained from SIDRA IBGE. After combining all of this data, it utilizes the Supply Chain Mapping Method (SEI-PCS), to link soy products from the original farm plot all the way to the consuming country. The approach considers both soybeans and soymeal and combines them into a standardized measure known as "equivalent soybean", based on mass balance calculations. The data used for this analysis is based on data from the years 2019 and 2020, as there were different commercial data sources and methodology used for the years 2004-2018. The years 2019-2020 are the most recent and relevant data available from Trase and make a good proxy for the current share of exports to the EU.

Table 1 demonstrates the value of the traded soy product in US dollars sent for export to all countries and to the EU. These values are based on the shipment volumes at the port of export, known as the freight on board value or FOB. The table reveals the distribution of soybean exports from different states in Brazil to the European Union. Rondonia has the largest share with 66% of its soybeans being sent to the EU, whereas São Paulo has the lowest share, with only 5% of its soybeans being exported to the EU. These share percentages will be used to determine the shock (increase in cost) that each state would face as a result of the EUDR requirements.

Table 1 – Share of exports of soy equivalents to EU (FOB - US$MM)

| Federal Units | Total Export of Equivalent Soy | Export to EU of Equivalent Soy | Share of Equivalent Soy Export to EU |
|---|---:|---:|---:|
| Mato Grosso | $7,313 | $1,185 | 16% |
| Paraná | $4,471 | $554 | 12% |
| Rio Grande do Sul | $3,404 | $267 | 8% |
| Goias | $2,457 | $297 | 12% |
| Mato Grosso do Sul | $2,258 | $354 | 16% |
| Bahia | $1,349 | $341 | 25% |
| Minas Gerais | $1,209 | $91 | 8% |

| | | | |
|---|---|---|---|
| São Paulo | $905 | $49 | 5% |
| Maranhão | $730 | $99 | 14% |
| Tocantins | $621 | $73 | 12% |
| Santa Catarina | $611 | $83 | 14% |
| Piauí | $332 | $44 | 13% |
| Pará | $306 | $94 | 31% |
| Rondônia | $227 | $151 | 66% |
| Total | $26,194 | $3,683 | 14% |

Source: Elaborated by the author.

As stated before and evidenced above, soy production and export to the EU is not uniformly distributed across Brazil and the total shock for each state would only reach a maximum value of 6% cost increase in the event that all its soy was exported to the EU. Multiplying this maximum incremental cost by the share export to EU of equivalent soy determines the shock value for each individual state. So for example, in Rondonia the share of exports to the EU is 66%, so 66% of the maximum incremental cost of 6% gives an estimated shock of 4% for Rondonia to the cost of soy production. Likewise, Bahia receives 25% of the maximal incremental cost of 6% giving an estimated shock of 1.5%, for Pará, and São Paulo with only 5% exports to the EU would receive an estimated shock of 0.3%. Table 2 shows the estimated shock for every soy producing federal state and lists them in descending order. States not listed have no exports to the EU and therefore no shock impacts. In the model the states are combined into 14 distinct regions, and the shock values are recalibrated to align with the model's parameters and can be found in Table 3 when discussing the simulation strategy.

The cost increase shock in the model was implemented as an increase in the production tax rate on soybean producers. This is an appropriate way of introducing the extra costs once, from a producer perspective, functioning as equivalent to a tax increase.

Table 2 – Shock values for the soy-producing federal states (%)

| Federal Units | Share of Equivalent Soy Export to EU | Maximum Incremental Cost | Shock Value |
|---|---|---|---|
| Rondônia | 66% | 6% | 4.0% |
| Pará | 31% | 6% | 1.8% |
| Bahia | 25% | 6% | 1.5% |
| Mato Grosso | 16% | 6% | 1.0% |
| Mato Grosso do Sul | 16% | 6% | 0.9% |
| Santa Catarina | 14% | 6% | 0.8% |
| Maranhão | 14% | 6% | 0.8% |
| Piauí | 13% | 6% | 0.8% |

| | | | |
|---|---|---|---|
| Paraná | 12% | 6% | 0.7% |
| Goias | 12% | 6% | 0.7% |
| Tocantins | 12% | 6% | 0.7% |
| Rio Grande do Sul | 8% | 6% | 0.5% |
| Minas Gerais | 8% | 6% | 0.5% |
| São Paulo | 5% | 6% | 0.3% |

Source: Elaborated by the author.

### *5.4. Model Closure*

The closure of the model is based on the work of De Souza Ferreira Filho et al.(2015) and consists of a set of variables, which will be considered exogenous and endogenous in the CGE model. In order to ensure a unique solution, it is important to establish certain external variables that will impact the system in the model and ensure that the number of variables within the system matches the number of equations present. The macroeconomic closing used in this paper is based on the following assumptions:

(i) The national supply of each labor skill type increases according to official projections;
(ii) Inter-regional real wage differentials drive labor movement between regions;
(iii) Within a region, labor of each skill type flows freely between activities;
(iv) Government consumption follows household consumption in each region;
(v) Regional household consumption follows regional wage income;
(vi) The level of employment is held fixed;
(vii) Capital stock is endogenous, adjusted to the rate of return across activities. Capital accumulates when the rate of return of an activity increases;
(viii) The trade balance is endogenous;
(ix) The GDP price index is the model's numéraire.

In the baseline, areas of unused land (natural forests) in regions where there are still natural stocks available are endogenous and determined by the transition matrix. In the policy scenarios there is conversion of unused land in the land-constrained regions, and land moves endogenously between Crop, Pasture, and Planted Forest uses.

### *5.5. Simulation strategy*

In a dynamic model, the first step is to run a simulation to establish a baseline scenario for the economy, to which different policy scenarios can be compared. This study will compare the baseline of the projected Brazilian economy up to 2030 to three different potential scenarios under the EUDR regulation on the Brazilian economy up to 2030. The three policy scenarios will be based on three different risk classification scenarios for both forest and non-forest ecosystems, since the EU haven't disclosed the risk classification list yet. Thus, we have the following scenarios:

**Baseline (Base):** Shocking our model with the commodity (average) price shocks in international markets for the historical period (2015 to 2022) and projecting the economy until 2030 based on past observed trends for GDP, population, and other variables. The baseline acts as if there are no EUDR restrictions on soy product exports at all.

**Policy Scenario 1 (1AMZN):** where an increase in costs for compliance is only applied to the regions of the Amazon Biome as they are considered high risk of deforestation areas.

**Policy Scenario 2 (2AMZCER):** where an increase in costs for compliance are applied to the regions of the Amazon and Cerrado Biomes because they are considered high deforestation risk areas.

**Policy Scenario 3 (3ALL):** where an increase in costs for compliance is applied to all regions of Brazil that export to the European Union.

The cost increases will be implemented in the model as increases in the rate of production taxes, as mentioned above. The size of the shock is small enough when compared to the total economy, that no tax revenue recycling is needed. The regions involved in each scenario can be seen in Table 3, below.

Table 3 – Value of shocks for each region under each Policy Scenario.

| Region | 1AMZN Shock | 2AMZCER Shock | 3ALL Shock |
|---|---|---|---|
| Rondonia | 4.0% | 4.0% | 4.0% |
| ParaAP | 1.8% | 1.8% | 1.8% |
| MtGrosso | 1.0% | 1.0% | 1.0% |
| MaToPi | 2.3% | 2.3% | 2.3% |
| Bahia | | 1.5% | 1.5% |
| MtGrSul | | 0.9% | 0.9% |
| GoiasDF | | 0.7% | 0.7% |
| MinasG | | 0.5% | 0.5% |
| SaoPaulo | | 0.3% | 0.3% |
| Parana | | 0.7% | 0.7% |
| RSul | | | 1.3% |
| AmazACRR | | | |
| RNordeste | | | |
| RSudeste | | | |

Source: Elaborated by the author.

# 6. RESULTS

## *6.1. National economic analysis*

The results of our analysis reveal that the effects of EUDR on the soybean supply chain will negatively impact the Brazilian economy. In Table 4 we outline the effects on key macroeconomic aggregates caused by shocks based on the three different scenarios described on the simulation strategy. The numbers show the difference between the baseline and each scenario tested from 2023-2030.

Table 4 – Effect in the main macroeconomic aggregates. Deviations from the baseline, accumulated (accumulated % change from 2023 to 2030)).

| VARIABLES | SCENARIOS | | |
|---|---|---|---|
| | 1AMZN | 2AMZCER | 3ALL |
| **REAL GROSS DOMESTIC PRODUCT (GDP)** | -0.001 | -0.002 | -0.003 |
| **REAL HOUSEHOLD CONSUMPTION** | -0.001 | 0.000 | -0.001 |
| **REAL GOVERNMENT CONSUMPTION** | 0.000 | 0.000 | -0.001 |
| **REAL INVESTMENT** | 0.000 | 0.003 | 0.004 |
| **EXPORT VOLUME** | -0.018 | -0.047 | -0.052 |
| **IMPORT VOLUME** | -0.015 | -0.036 | -0.041 |
| **REAL WAGE** | -0.011 | -0.022 | -0.026 |
| **EXPORT PRICE INDEX** | 0.019 | 0.045 | 0.052 |
| **CONSUMER PRICE INDEX** | -0.001 | -0.002 | -0.002 |

Source: Elaborated by the author.

The initial observation is that there will be a marginal contraction to the Brazilian economy. Model results show negative variations in values of real GDP ranging from 0.001% from the least restrictive scenario (Amazon biome only) to a decrease of 0.003% for the most restrictive scenario (All biomes included), a very small national impact. In harmony with that, the changes in real household consumption, real government consumption, and real investments are almost unnoticed. Overall, there was no significant impact on GDP, consumers and government consumption and investments at the aggregate level. This small national effect was expected since the shock was applied to only one sector that has an estimated GDP of 5% considering the interdependencies with inputs, services and agroindustry.

There are fluctuations in the export volumes, the figures vary from -0.018 from Amazon biome scenario (1AMZN) to -0.052 in the all biomes scenario (3ALL). The exports drop due to the increased cost of production of soybeans, one of the main national commodities sent overseas. The volume of imports decreased on a smaller scale in relation to exports, alternating from minus 0.015 to 0.041. This change is firstly attributed to a decrease in inputs for soybean production, such as fertilizers. And to the contraction of the economy without an increase in consumption. In addition to this, we also detect a currency devaluation, which impacts Brazilian trade.

The real wage had adverse variations as well. The numeric data changed from - 0.011 from Amazon region only (1AMZN) to minus 0.026 from all regions (3ALL) scenarios. Therefore, Brazilian workers will experience decreased salaries on every policy tested.

The export price oscillated positively on a similar magnitude to export volumes. This was expected given the direct relation to the shock applied. Additionally, there was small negative variation in the consumer price index, which means, that the representative basket of goods and services of consumers will have a deflation compared to the expected baseline, what is related to the observed fall in GDP. The effect of the model on the consumer price index was small, being -0.001 for the first scenario (1AMZN) and -0.002 for the last two scenarios (2 AMZCER, 3ALL).

To better understand the impacts on these macroeconomic aggregates it is beneficial to examine how the EUDR policy will impact the exports and overall output per industry sector. In Figure 4, we see the changes in export volume across 37 industries, which once again show clear drops in soybean exports (with drops of 0.86%, 1.92%, and 2.26% for scenarios 1, 2, and 3, respectively). These drops in soybean exports are accompanied by increases in exports for other agricultural products, primarily cotton, corn, and other permanent crops. The increase in other exports does not completely offset the drop in soybean exports, as a result, the total export volume decreases due to the policy change by 0.015% in scenario 1, 0.036% in scenario 2, and 0.041% in scenario 3.

Interestingly, the first scenario presents a different combination of increased outputs compared to the other two scenarios, which can be attributed to regional variation in industries. Industries such as Aquaculture and Meat experience higher increases in the first scenario, while Coffee and Orange see higher increases in the second scenario, and Rice, Wheat, and Swine are highlighted in the third scenario, 3ALL. This is due to concentration of the production in certain regions, for example Aquaculture is relevant in ParaAP so it should see an increase with producers moving away from soy in the only Amazon scenario, this effect is quite interesting that the EUDR can influence the regional competitive advantages of different food chains. Overall, with alternative crops failing to fully compensate for the decline in soybean exports, and the possible future inclusion of corn to the regulation, the Brazilian agriculture producers' ability to compensate exports is challenging.

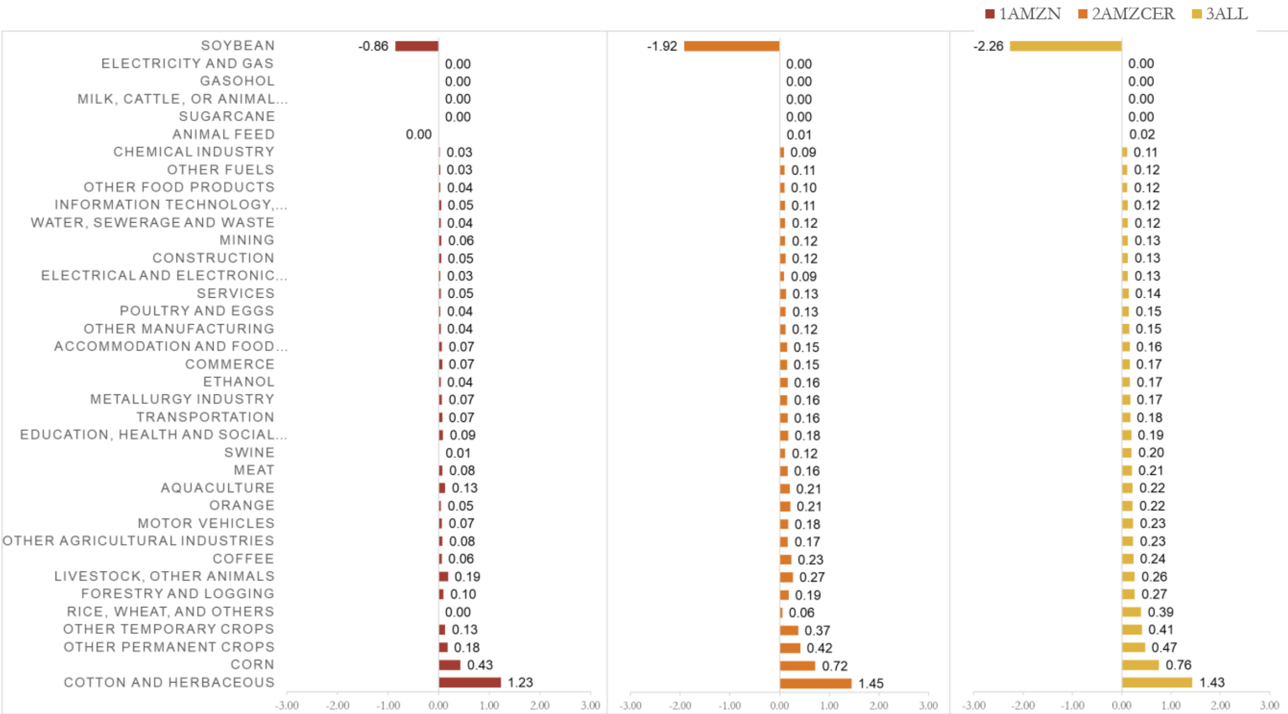

Figure 4 – Model results for national exports volume (% change from 2023 to 2030)
Source: Elaborated by the author.

Figure 5 shows the change in industrial output nationally across 38 different industries for each scenario. With the increased costs associated to soy production, there will be a reduction in soybean production, with a decrease of 0.68% for scenario 1, a decrease of 1.48% for scenario 2, and a decrease of 1.74% for scenario 3. Most of that capital and labor will be allocated instead to other agricultural industries. Mainly cotton and corn in the first scenario, added to that coffee, rice, wheat and other permanent crops in the other two scenarios.

Next, we look at the social and distributive impacts through different levels of household income and labor wages. Household income levels are categorized as POF with the lowest level labeled as POF1 and the highest level as POF10. Similarly, wage levels are categorized as OCC with OCC1 category has the lowest qualification (lowest salary range) and OCC10 category is considered the highest qualification (Highest salary range).

Household consumption's slight fluctuations at the aggregate level mask more substantial differences when disaggregated by income ranges. As shown in Figure 6, household consumption is categorized by income level. The chart reveals that, across all scenarios, lower-income levels (POF1 and POF2) experience an increase in household consumption, more pronounced in scenario 2 and 3. While middle and higher income households displayed a decrease in their household consumption across all scenarios, excluding the highest income tier. Part of this reduction can be traced back to a decrease in wages, but reduction in employment is also a factor: soybean production is particular intensive in the OCC2 to OCC5 wage groups, which are particularly affected negatively by the reduction in production. The impact to the lower-income households is in the opposite direction, driven by the demand for ranching workers with the substitution to meat industry that requires 5 times more workers compared to the soy.

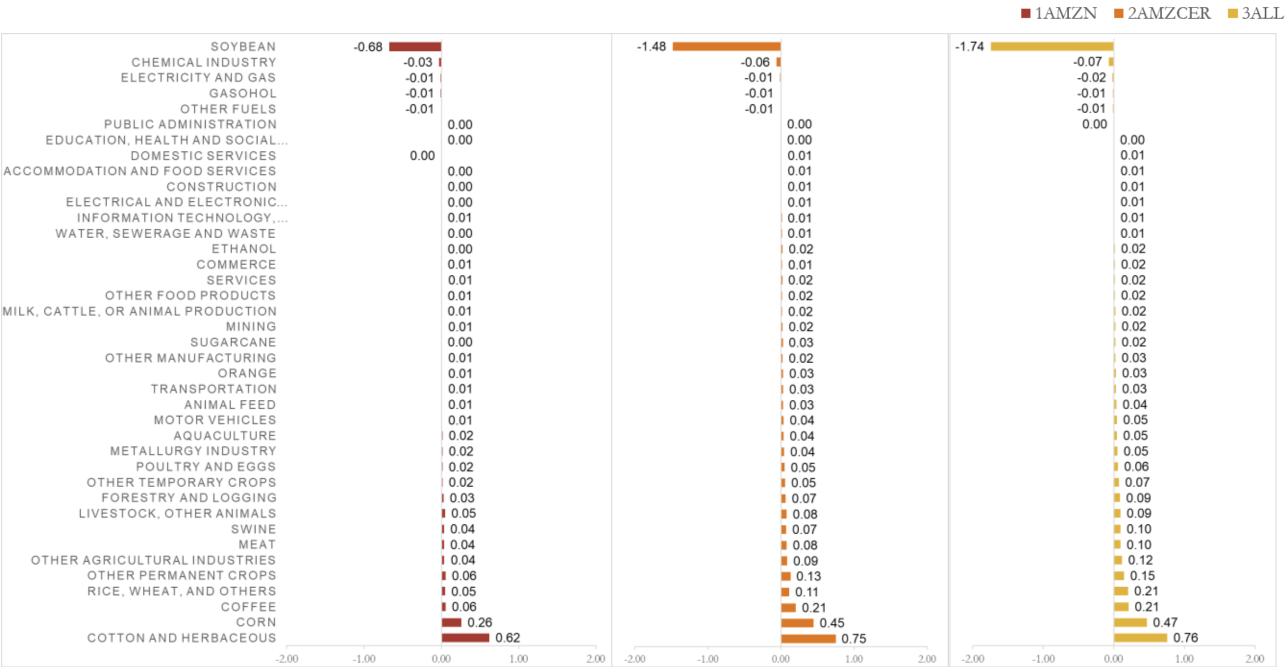

Figure 5 – Effect in the industry outputs nationally (% change from 2023 to 2030)
Source: Elaborated by the author.

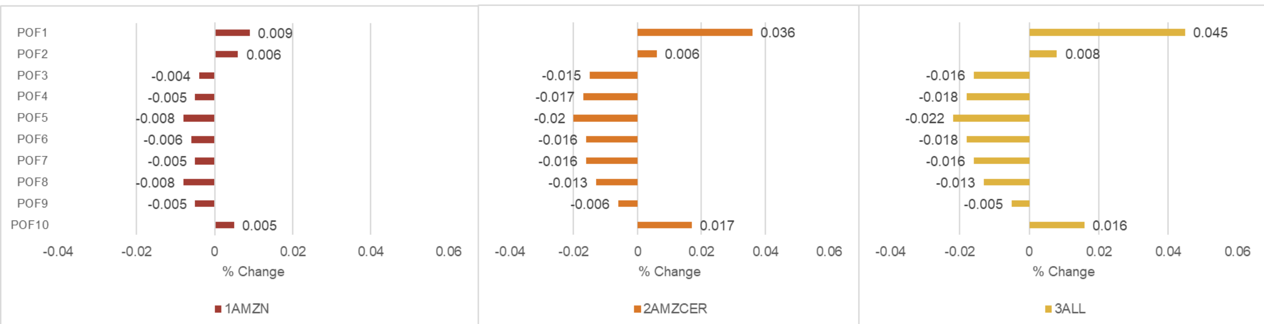

Figure 6 – Effect in the total real household consumption nationally (% change from 2023 to 2030)
Source: Elaborated by the author.

The social impact of complying with EUDR can also be seen in Figure 7, which shows the results of real wages per salary scales. The results shows that there is a noticeable contraction in real wages for categories spanning OCC3 to OCC7, with the decline particularly significant for workers in the OCC3 and OCC4 categories. The change in real wage is much more drastic when comparing scenario 1 and 2, than scenario 2 and 3 as the changes between 2AMZCER and 3ALL plateau toward the maximum possible effect. Leading us to infer that if the EUDR includes the biome Cerrado, the effects would arguably be similar to considering the all producing federal units. Interesting to note is that for the very lowest level of salary, scenarios 2 and 3 show a very slight increase in wage. In all scenarios the highest wages are relatively unaffected.

Figure 7 – Total wage bill (% change from 2023 to 2030)
Source: Elaborated by the author.

### *6.2. Regional economic analysis*

In addition to providing a national overview, we also analyze the regional level, as the TERM-BR model allows us to examine each region as a distinct economy, which helps us appreciate the most prominent effects of the shock. Since the significance of the soybean industry varies across regions, the effects of the EUDR will also differ greatly.

Figure 8 outlines the changes in real Gross Domestic Product (GDP) per region for all three scenarios, enabling observations regarding local economic dynamics. Generally, the changes are minor, with the most notable impact occurring in MtGrosso during scenario 1, where the cumulative difference from 2023 to 2030 is minus 0.09%. This is attributed to a substitution effect in crops; as soy production declines, there's available land for cultivating cotton and corn. Additionally, the currency devaluation slightly increases exports compensating the results for GDP. In scenarios 2 and 3 more regions also experience a decrease in real GDP such as Bahia. Also, the economic impact for MtGrosso and MaToPi will attenuate as more federal units are identified as high-risk in these scenarios. Conversely, MtGrSul may benefit if it is excluded from high-risk areas, and other states are considered, but there may be a detrimental effect if it is also categorized as hazardous. Importantly, regions like GoiasDf, ParaAP, Parana, RSudeste, MinasG, RNordeste, and SaoPaulo did not experience an economic upheaval because of European measures. Of particular interest in this group is Parana, one of Brazil's largest soybean-producing regions, which exports 12% of its soybeans to the EU.

In Figure 9 we have real household consumption per regions, and just as seen above in real GDP, in scenario 1 MtGrosso and Rondonia face the strongest impacts, with MaToPi and ParaAP also contracting to lesser extents. Whereas the other regions face no change or even slight upticks in household consumption. But, in scenario 2 and 3 regions like MtGrSul, Bahia, GoiasDF and Parana become impacted and face contractions in household consumption. The areas least affected are those less dependent on the soy trade today.

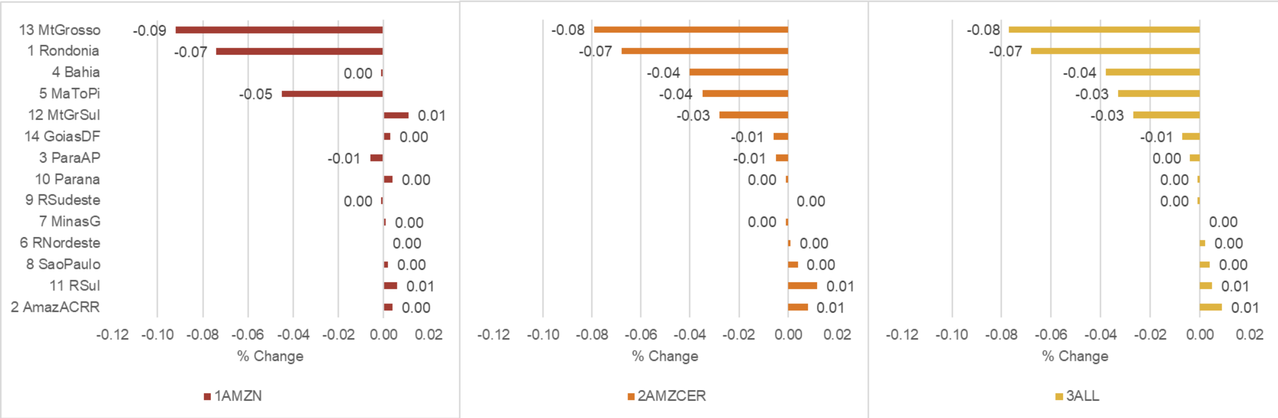

Figure 8 – Real GDP per region (% change from 2023 to 2030)
Source: Elaborated by the author.

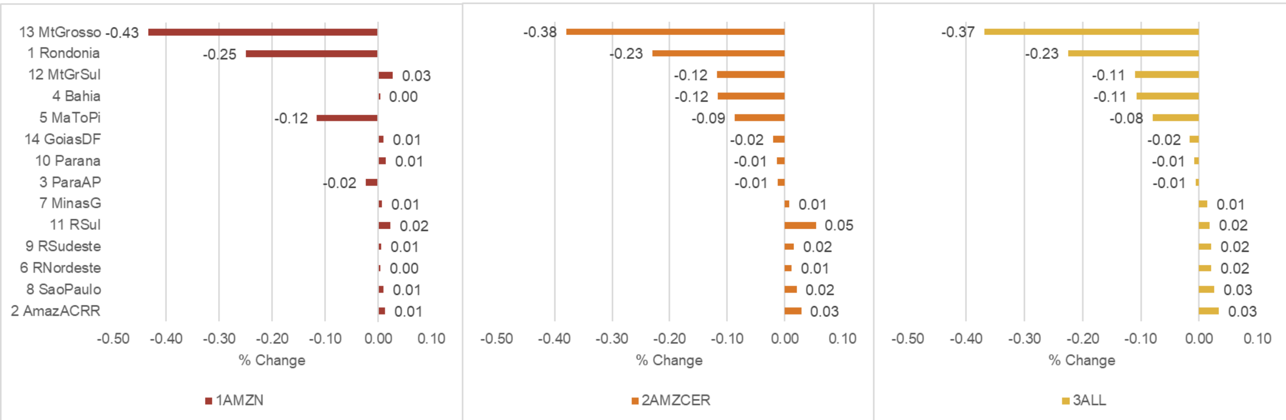

Figure 9 – Real Household consumption per region (% change from 2023 to 2030)
Source: Elaborated by the author.

Figure 10 – Model results for exports volume regionally (% change from 2023 to 2030)
Source: Elaborated by the author.

Figure 11 – Model results for real wage regionally (% change from 2023 to 2030)
Source: Elaborated by the author.

Table 5 – Effect in the agricultural industry outputs regionally (% change from 2023 to 2030).

| Regions | Rice, Wheat, and Others | | | Corn | | | Cotton and Herbaceous | | | Sugarcane | | | Soybean | | | Other Temporary Crops | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1AMZN | 2AMZCER | 3ALL | 1AMZN | 2AMZCER | 3ALL | 1AMZN | 2AMZCER | 3ALL | 1AMZN | 2AMZCER | 3ALL | 1AMZN | 2AMZCER | 3ALL | 1AMZN | 2AMZCER | 3ALL |
| 1 Rondonia | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.5 | 1.4 | 1.4 | 0.6 | 0.6 | 0.6 | -10.2 | -10.1 | -10.0 | 0.9 | 0.8 | 0.8 |
| 2 AmazACRR | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.2 | -0.2 | -0.2 | -0.1 | -0.1 | -0.1 | 0.2 | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 |
| 3 ParaAP | 0.2 | 0.2 | 0.1 | 0.2 | 0.3 | 0.3 | 0.0 | -0.1 | -0.1 | 0.1 | 0.0 | 0.0 | -4.8 | -4.6 | -4.6 | 0.1 | 0.1 | 0.1 |
| 4 Bahia | -0.1 | 0.7 | 0.5 | -0.1 | 0.4 | 0.4 | -0.4 | 0.3 | 0.3 | -0.1 | 0.4 | 0.4 | 0.2 | -4.3 | -4.3 | 0.0 | 0.2 | 0.2 |
| 5 MaToPi | 0.5 | 0.5 | 0.4 | 0.7 | 0.6 | 0.6 | 0.3 | 0.2 | 0.2 | 0.5 | 0.3 | 0.3 | -1.8 | -1.6 | -1.6 | 0.2 | 0.2 | 0.2 |
| 6 RNordeste | -0.1 | -0.1 | -0.2 | -0.2 | -0.3 | -0.3 | -0.3 | -0.4 | -0.4 | -0.1 | -0.1 | -0.1 | 0.7 | 1.4 | 1.4 | 0.0 | -0.1 | -0.1 |
| 7 MinasG | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.3 | -0.3 | -0.3 | 0.0 | -0.1 | -0.1 | 0.3 | -0.9 | -0.9 | 0.0 | 0.0 | -0.1 |
| 8 SaoPaulo | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.5 | -0.5 | -0.5 | 0.0 | -0.1 | -0.1 | 0.3 | -0.5 | -0.5 | 0.0 | -0.1 | -0.2 |
| 9 RSudeste | 0.0 | -0.1 | -0.2 | -0.1 | -0.1 | -0.1 | -0.3 | -0.3 | -0.3 | 0.0 | -0.2 | -0.2 | 0.3 | 0.6 | 0.6 | 0.0 | -0.1 | -0.1 |
| 10 Parana | 0.0 | 0.4 | 0.3 | -0.1 | 0.4 | 0.4 | -0.5 | -0.1 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | -1.7 | -1.6 | 0.0 | 0.2 | 0.2 |
| 11 RSul | -0.1 | -0.1 | 0.1 | -0.1 | -0.1 | 0.2 | -0.7 | -0.8 | -0.4 | -0.1 | -0.4 | -0.1 | 0.1 | 0.2 | -1.5 | 0.0 | -0.1 | 0.1 |
| 12 MtGrSul | -0.1 | 0.6 | 0.5 | -0.1 | 0.6 | 0.6 | -0.4 | 0.4 | 0.4 | -0.1 | 0.3 | 0.3 | 0.3 | -2.1 | -2.0 | -0.2 | 0.3 | 0.2 |
| 13 MtGrosso | 1.2 | 1.1 | 1.0 | 1.3 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.3 | 1.0 | 1.0 | -1.7 | -1.6 | -1.5 | 0.8 | 0.7 | 0.6 |
| 14 GoiasDF | -0.1 | 0.3 | 0.2 | -0.1 | 0.3 | 0.3 | -0.4 | 0.1 | 0.1 | -0.1 | 0.1 | 0.1 | 0.2 | -1.1 | -1.1 | -0.1 | 0.1 | 0.1 |

| Regions | Orange | | | Coffee | | | Other Permanent Crops | | | Livestock, other Animals | | | Milk, Cattle, or Animal Production | | | Forestry and Logging | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1AMZN | 2AMZCER | 3ALL | 1AMZN | 2AMZCER | 3ALL | 1AMZN | 2AMZCER | 3ALL | 1AMZN | 2AMZCER | 3ALL | 1AMZN | 2AMZCER | 3ALL | 1AMZN | 2AMZCER | 3ALL |
| 1 Rondonia | 1.6 | 1.6 | 1.5 | 2.0 | 2.0 | 2.0 | 0.7 | 0.7 | 0.7 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 2 AmazACRR | 0.0 | 0.0 | 0.0 | -0.2 | -0.2 | -0.2 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 |
| 3 ParaAP | 0.2 | 0.2 | 0.2 | 0.4 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 |
| 4 Bahia | 0.0 | 0.2 | 0.2 | 0.0 | 1.0 | 1.0 | 0.0 | 0.5 | 0.5 | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 | 0.2 | 0.2 |
| 5 MaToPi | 0.6 | 0.5 | 0.5 | 1.0 | 0.8 | 0.8 | 0.5 | 0.4 | 0.4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 |
| 6 RNordeste | 0.0 | -0.1 | -0.1 | 0.0 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.4 | -1.2 | -0.3 |
| 7 MinasG | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | -0.1 | -0.2 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 SaoPaulo | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | -0.1 | -0.2 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 RSudeste | 0.0 | 0.0 | -0.1 | 0.0 | 0.1 | 0.1 | -0.1 | -0.2 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 Parana | 0.0 | 0.3 | 0.3 | 0.0 | 0.7 | 0.7 | -0.1 | 0.3 | 0.2 | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 |
| 11 RSul | 0.0 | -0.1 | 0.1 | 0.0 | 0.0 | 0.5 | 0.0 | -0.1 | 0.1 | 0.0 | -0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| 12 MtGrSul | 0.0 | 0.7 | 0.7 | 0.0 | 1.1 | 1.1 | -0.2 | 0.5 | 0.5 | 0.0 | 0.1 | 0.2 | 0.0 | 0.2 | 0.1 | 0.0 | 0.3 | 0.3 |
| 13 MtGrosso | 1.0 | 0.8 | 0.8 | 1.4 | 1.3 | 1.3 | 0.8 | 0.7 | 0.6 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 0.6 | 0.6 | 0.5 |
| 14 GoiasDF | 0.0 | 0.3 | 0.3 | 0.0 | 0.6 | 0.6 | -0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.1 |

Figure 10 displays percent change in export volumes regionally for the three scenarios. Despite a regional economic contraction, the state of Mato Grosso experiences the highest changes in the three scenarios ranging from 0.73 to 0.76. There is also an increase across scenarios in Rondonia, MtGrSul, GoiasDF, RNordeste and MinasG. In contrast, MaToPi, ParaAP and AmazACRR will have negative variations also across scenarios. Bahia and Parana showed a slight increase in the first scenario but showed relevant decrease in the other two scenarios. Which shows that they would be benefited from being skipped the high-risk classification. It is important to highlight that there will be a decrease in national export volume in 2030 compared to the baseline in all scenarios. However, for MtGrosso and Rondonia the exports increase due to the substitution effect to other exporting agricultural crops specially cotton that has a high portion of its total production exported. And the currency devaluation generated by the shock that stimulate exports.

The increase in exports of MtGrosso and Rondonia was not associated with labor-intensive industries, that's why they face a drop in wages displayed in Figure 11. The loss of jobs puts negative pressure on labor wages, resulting in them either decreasing or staying the same in almost every region in Brazil. In scenarios 2 and 3, this effect takes place in more regions, causing wages to decrease almost across the board.

In table 5 we see the industry outputs from the agriculture sectors for each region. Rondonia with the highest decrease in soybeans counterbalance with stronger increase in Coffee, Orange, Cotton, Corn, and others. The same effect is seen in Mato Grosso but at a smaller scale. Cotton has an overall decrease. RNordeste has an inverse effect of increase in Soybeans and decrease in Forestry & Logging, but this is not necessarily realistic given that the shock was not applied in the region because there is not a significant production to EU and the region would be under the EUDR effect as well.

Figure 12 shows how the output of the soy industry changes according to the region. In scenario 1, Rondonia and ParaAP show large decreases in output, while MtGrosso and MaToPi also show smaller decreases. The remaining regions show almost no change or even slightly positive changes in output. In the more restrictive scenarios 2 and 3, the decrease in soy output spreads to more places, leaving Rondonia, ParaAP, and Bahia as the most affected regions. However, RNordeste, RSudeste, and AmazACRR see their soybean production expand regardless of policies.

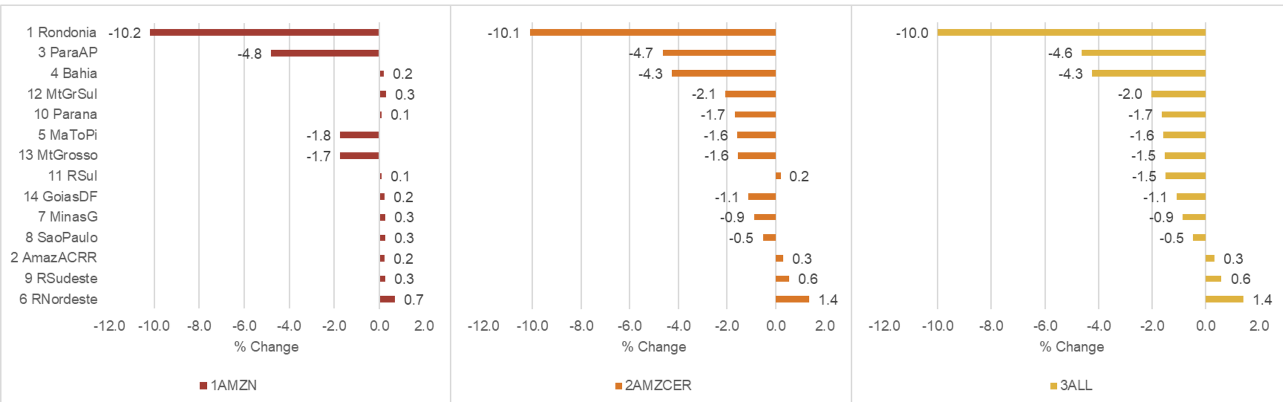


Figure 12 – Model results for soybeans industry output regionally (% change from 2023 to 2030)
Source: Elaborated by the author.

### *6.3. Environmental Impact Analysis*

The primary objective of the EUDR is to eliminate the EU's contribution to deforestation caused by the import of commodities. The LUC module of TERM-BR allows us to track the Land Use Change across the different policy scenarios, in which land is classified into four different use cases; Crop, Pasture, Planted Forest (in which trees are planted for logging and commercial purposes) and Unused (which represents the growth of natural forests). The values for Land Use Change are presented in Figure 13 below.

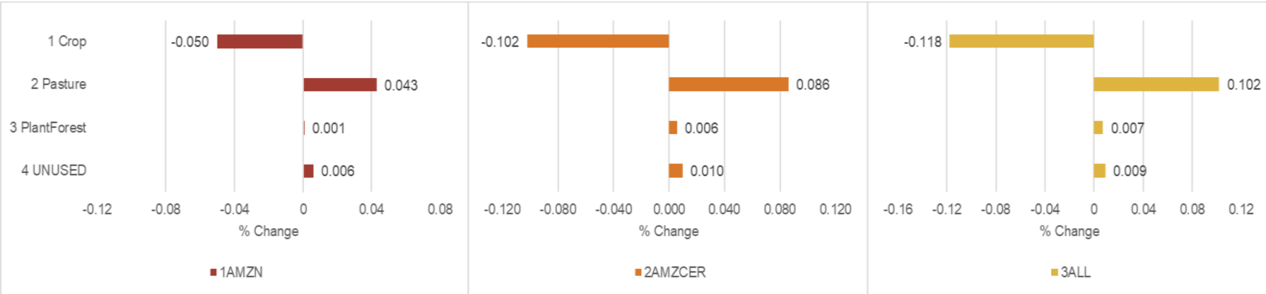


Figure 13 – Model results for National Change broad areas in hectares
Source: Elaborated by the author.

In our earlier analysis it was shown that much of the drop in soy production was substituted for other agricultural crops such as cotton, corn, rice and wheat so most crop land was reutilized. But a small percentage of crop land was converted for other purposes. For scenario 1, which deals with the Amazon biome, the drop in crop land is mostly converted to pasture, and a tiny fraction is converted back into unused land. For scenarios 2 and 3, there is an even greater reduction in crop land, which again is mostly converted into pasture, but there are also slightly positive changes in both planted and natural forests. Thus, this graph shows that the EUDR policies can and will have positive effects in curbing deforestation. In Figures 14, 15, and 16 we see the regional breakdown of land use change for Crop land, Pasture, and Natural Forest respectively.

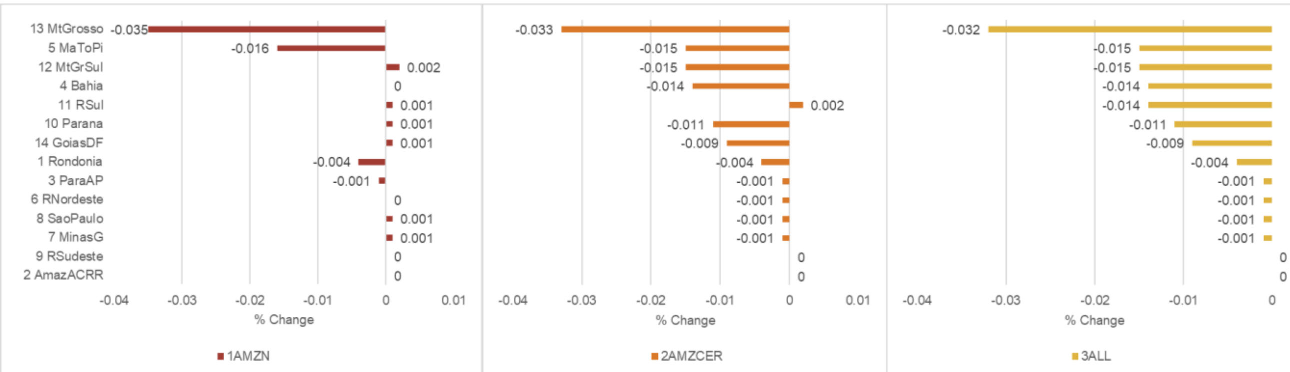


Figure 14 – Change in Crop Land areas, millions of hectares (c) regionally
Source: Elaborated by the author.

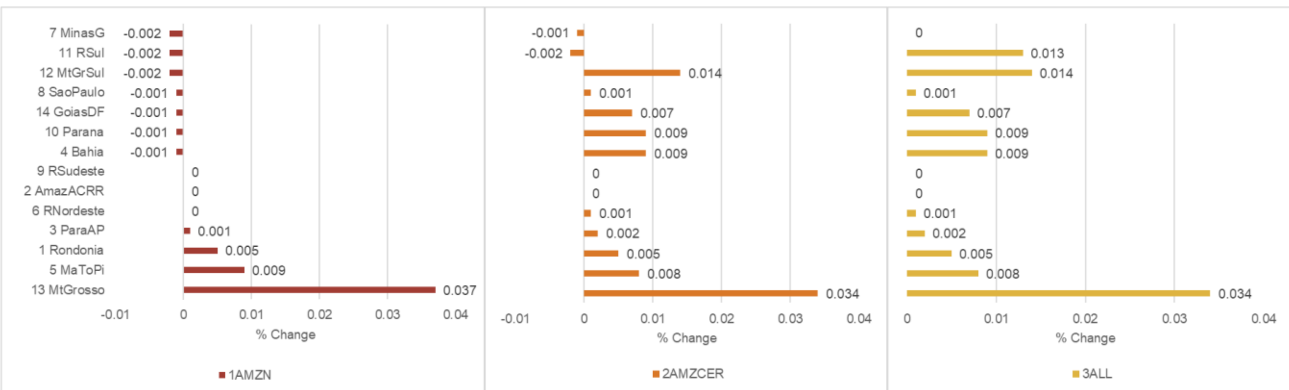


Figure 15 – Change in Pasture areas, millions of hectares (c) regionally

Source: Elaborated by the author.

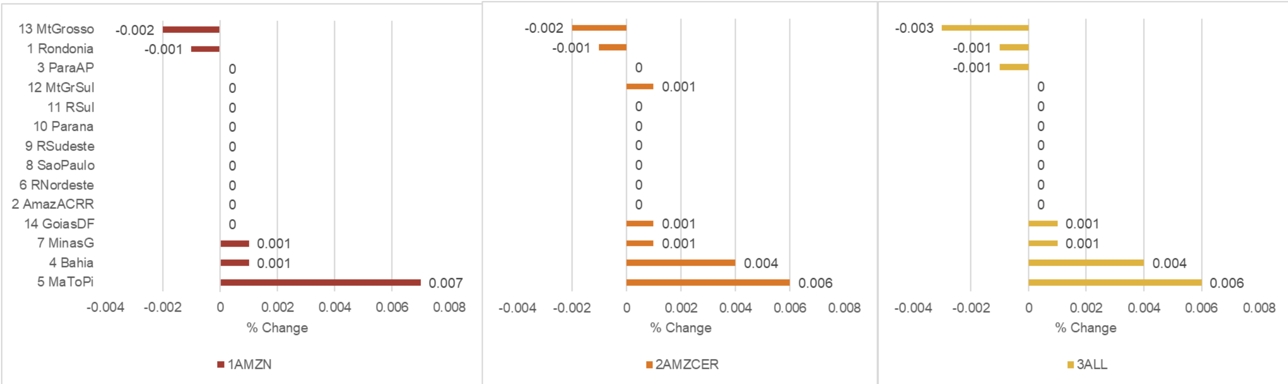


Figure 16 – Change in Natural Forests areas, millions of hectares (c) regionally
Source: Elaborated by the author.

Figure 14 shows the change in crop land drops primarily in MtGrosso and MaToPi in scenario 1, whereas in scenarios 2 and 3 show similar reductions in each of the affected regions. Figure 15 shows the regions which saw an increase in pastures. In scenario 1 the increases are concentrated in MtGrosso, MaToPi, and Rondonia, while in scenarios 2 and 3 there are increases in pasture in most regions. Figure 16 shows the change in natural forests across the three scenarios. In each scenario, MaToPi and Bahia had natural forest growth, whereas MtGrosso and Rondonia experienced natural forest loss. Most other regions saw no change.

While the land use changes demonstrate positive effects in reducing deforestation, the conversion of crop land to pasture is kind of a double-edged sword. Ranching is the biggest emitter of emissions in agriculture due to the gases released by livestock digestion. Thus, in some of the regions with increased pasture there is a tendency to increase emissions as well, Figure 17 shows the change in emissions by region. In the first scenario, emissions increase primarily in MtGrosso, Rondonia and MaToPi, and are practically zero or negative in the rest of the regions. In scenarios 2 and 3 as more regions convert crop land to pasture, some but not all of the other regions switch from a net negative to a net positive change.


Figure 17 – Total emissions regionally (% change)
Source: Elaborated by the author.

The EUDR should be effective in reducing deforestation, however the increase in emissions from the targeted regions caused by the conversion of crop land to pastures is noteworthy. The EUDR regulation does include cattle as one of their targeted commodities but would have less of an impact on Brazilian ranching as most beef produced in Brazil is consumed domestically.

## 7. FINAL CONSIDERATIONS

As we conclude this paper, it is pertinent to reflect on the possible interpretations and implications of the study results which suggest a multi-faceted impact on the Brazilian economy and emissions resulting from complying with EUDR in the case of the soybean supply chain.

Our research has indicated a potential decrease in deforestation, a conclusion that coincides with intentions of the regulation proposed by the European Parliament. Notably, this decrease in deforestation is linked to a negative, but small impact on national GDP and a devaluation of the national currency, as the results indicated.

Middle-class households may experience a small decline in their consumption capacity due to the reduction in wages. Economically, this is a flag to monitor the quality of life for these households. A substitution effect in the agricultural crops is expected, including coffee, corn, orange, rice, and wheat emerging as viable substitutes for soybean production. Such a shift is also indicated in the export volumes, with replacement likely from cotton and corn. It is important to highlight that these alternative crops will not offset the reduction in production and exports of soybeans. Also, coffee is included in EUDR as a commodity that drives deforestation, just like soy. And corn is still to be decided for its inclusion, thus potentially not being a viable alternative crop.

Regionally, the impact shows disparity. For instance, MtGrosso and Rondonia are projected to be most economically negatively impacted, aggravating regional economic inequality. The lack of income convergence between regions causes social disparities and limits economic development in certain areas. The concentration of wealth in more developed regions, such as the Southeast, to the detriment of regions like the North and Northeast, contributes to the perpetuation of poverty and social exclusion. Therefore, the regulation will potentially harm income convergence among Brazilian regions. The emissions regionally will slightly reduce in most regions, but increase in MtGrosso, Rondonia, MaToPi and ParaAP due to increase in land use change to pasture as ranching is also an alternative to soy production.

An economic downturn was also predicted for MaToPi and Bahia, areas that have increased agricultural production in recent years and that have more forest land with potential for crop. The results display reduction in deforestation for these regions. Important to highlight that Cerrado biome was not decided yet for its inclusion and scenario 2 showed on many angles that this biome inclusion will have almost the same impact as classifying the whole country of Brazil as high-risk, results observed in scenario 3 of All biomes.

Parana, however, is anticipated to remain relatively unaffected by the EU measures, one of the main producers of soybeans in the country. GoiasDf, ParaAP, RSudeste, MinasG, RNordeste, and Sao Paulo also won't be significantly affected by the regulation economically and environmentally.

These interpretations prompt us to contemplate the web of complex factors inherent in the agriculture, economy, and environmental trade-offs of the regions being studied. As always, it is paramount to consider both the intended and unintended consequences of policy actions and to explore innovative solutions to address the challenges that lie ahead. Remind the limitation of this study that cannot estimate leakage from exports to other nations. Future research applying shocks directly to costs or a negative technology, as well to all commodities covered could deep the understanding of this innovative policy instrument from EU. carve out a path for such solutions while continuing the essential work of tracking these intricate dynamics.

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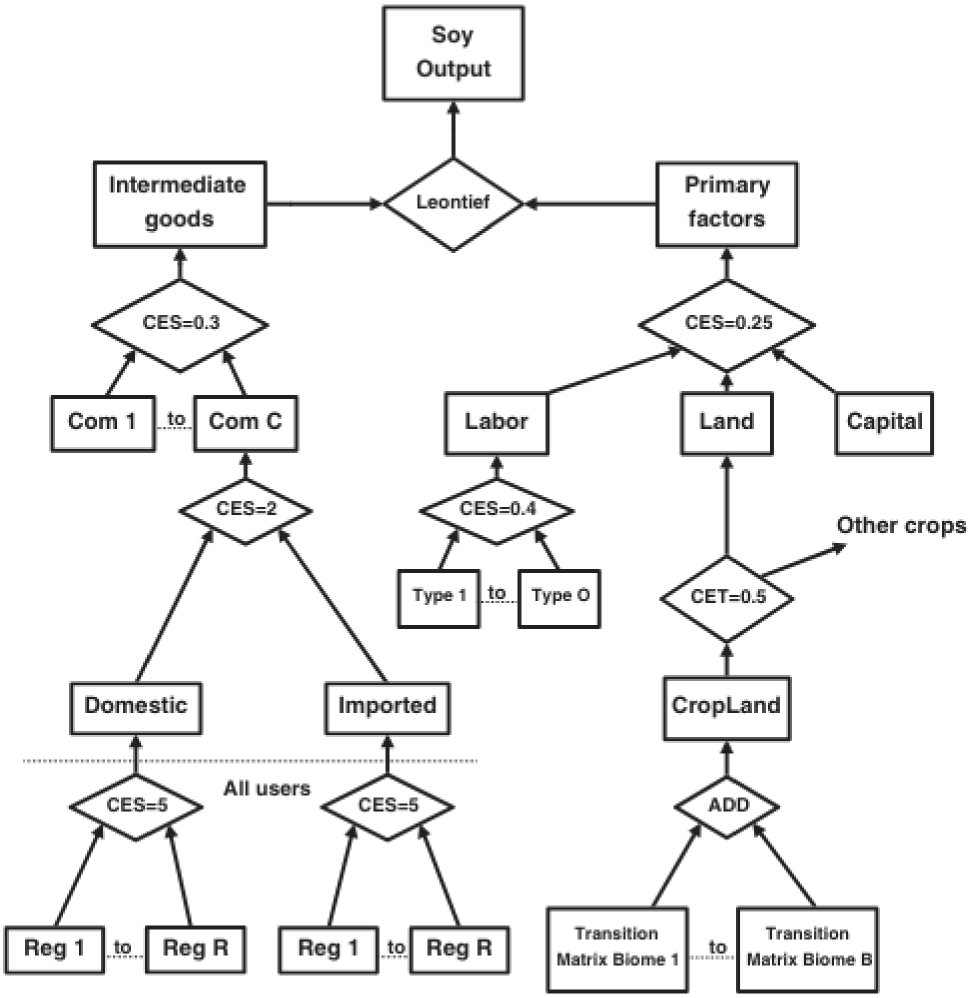
# 9. APPENDIX

## A. *TERM-BR Production nesting structure, with typical elasticities*

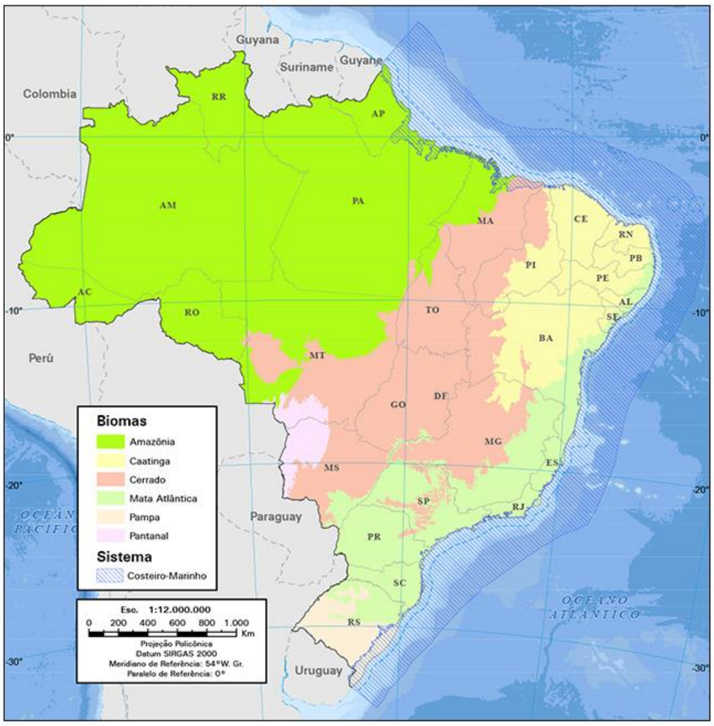



Source: Ferreira Filho, et al. 2015

## B. Table with grouped regions, federal states and biomes

| Grouped Regions | Federal States | Biomes |
|---|---|---|
| Rondonia | Rondonia | Amazon |
| Bahia | Bahia | Cerrado, Caatinga and Mata Atlantica |
| Amazacrr | Amazonas and Roraima | Amazon |
| ParaAp | Para and Amapa | Amazon |
| Matopi | Maranhão, Tocantins e Piaui | Amazon, Cerrado and Caatinga |
| Rnordeste | Ceara, Rio Grande do Norte, Paraiba, Pernanbuco, Alagoas, Sergipe | Caatinga e Mata Atlantica |
| Mtgrsul | Mato Grosso do Sul | Cerrado and Pantanal |
| Rsudeste | Espirito Santo and Rio de Janeiro | Mata Atlantica |
| Saopaulo | São Paulo | Cerrado e Mata Atlantica |
| Parana | Parana | Mata Atlantica |
| Rsul | Rio Grande do Sul e Santa Catarina | Pampa and Mata Atlantica |
| Mtgrosso | Mato Grosso | Amazon, Cerrado and Pantanal |
| Minasg | Minas Gerais | Cerrado e Mata Atlantica |
| Goiasdf | Goias e Distrito Federal | Cerrado |

## C. Map of Brazilian Biomes and Federal States




Fonte: IBGE

## D. Table with 39 sectors and commodities

| |
|---|
| Coffee |
| Corn |
| Orange |
| Rice, Wheat, and Others |
| Other Agricultural Industries |
| Other Permanent Crops |
| Metallurgy Industry |
| Motor Vehicles |
| Sugarcane |
| Other Temporary Crops |
| Mining |
| Construction |
| Ethanol |
| Other Manufacturing |
| Cotton and Herbaceous |
| Aquaculture |
| Forestry and Logging |
| Electrical and Electronic Industries |
| Other Food Products |
| Livestock, other Animals |
| Meat |
| Information Technology, Communications, and Financial Activities |
| Transportation |
| Swine |
| Water, Sewerage and Waste |
| Milk, Cattle, or Animal Production |
| Poultry and Eggs |
| Animal Feed |
| Other Fuels |
| Accommodation and Food Services |
| Commerce |
| Gasoline |
| Electricity and Gas |
| Domestic Services |
| Education, Health and Social Services |
| Public Administration |
| Chemical Industry |
| Soybean |

## *E. Transition matrices for land use change (Mha). Average annual changes.*

Parana

| ATRANS4 | 1 Crop | 2 Pasture | 3 PlantForest | 4 Unused | Total |
|---|---|---|---|---|---|
| 1 Crop | 10.4 | 0.1 | 0.0 | 0.1 | 10.6 |
| 2 Pasture | 0.1 | 3.9 | 0.0 | 0.1 | 4.1 |
| 3 PlantForest | 0.0 | 0.0 | 1.6 | 0.0 | 1.6 |
| 4 Unused | 0.0 | 0.0 | 0.0 | 3.5 | 3.6 |
| Total | 10.6 | 4.1 | 1.6 | 3.6 | 19.9 |

MtGrosso

| ATRANS4 | 1 Crop | 2 Pasture | 3 PlantForest | 4 Unused | Total |
|---|---|---|---|---|---|
| 1 Crop | 14.0 | 0.1 | 0.0 | 0.0 | 14.1 |
| 2 Pasture | 0.2 | 23.3 | 0.0 | 0.1 | 23.6 |
| 3 PlantForest | 0.0 | 0.0 | 0.3 | 0.0 | 0.3 |
| 4 Unused | 0.1 | 0.4 | 0.0 | 51.8 | 52.3 |
| Total | 14.2 | 23.9 | 0.3 | 51.9 | 90.3 |

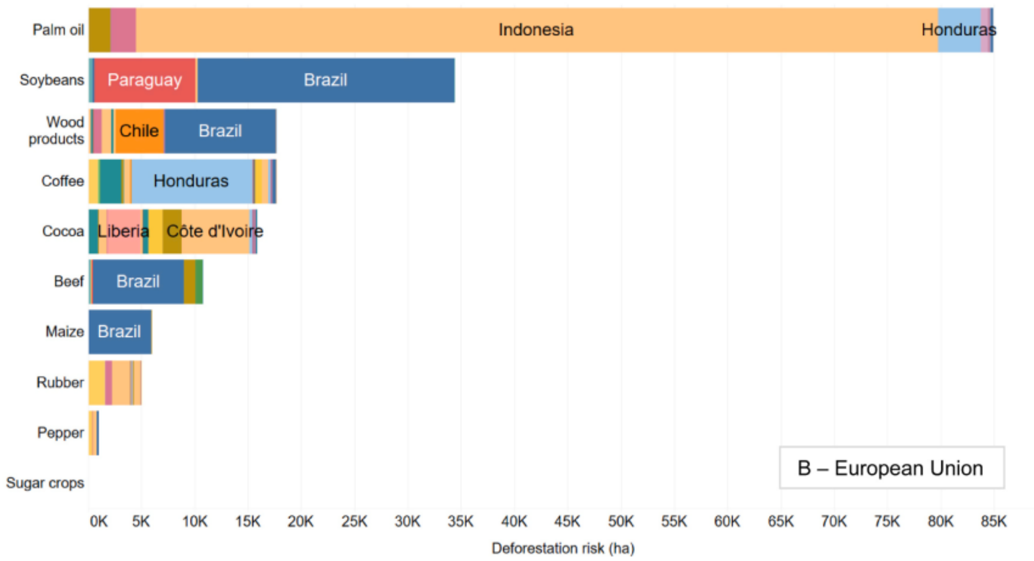
Brasil

| ATRANS4 | 1 Crop | 2 Pasture | 3 PlantForest | 4 Unused | Total |
|---|---|---|---|---|---|
| 1 Crop | 75.7 | 0.8 | 0.1 | 0.4 | 76.9 |
| 2 Pasture | 1.4 | 164.7 | 0.2 | 2.7 | 169.1 |
| 3 PlantForest | 0.1 | 0.1 | 9.7 | 0.1 | 9.9 |
| 4 Unused | 0.7 | 3.6 | 0.2 | 591.0 | 595.5 |
| Total | 77.9 | 169.2 | 10.2 | 594.2 | 851.5 |

## F. Soy commodity as percent of national and regional GDPs.

| Regions | Soy share of national GDP | Soy share on each region's GDP |
|---|---|---|
| 1 Rondonia | 0.02% | 2.63% |
| 2 AmazACRR | 0.00% | 0.10% |
| 3 ParaAP | 0.03% | 1.13% |
| 4 Bahia | 0.12% | 2.91% |
| 5 MaToPi | 0.16% | 6.39% |
| 6 RNordeste | 0.00% | 0.00% |
| 7 MinasG | 0.09% | 0.92% |
| 8 SaoPaulo | 0.06% | 0.18% |
| 9 RSudeste | 0.00% | 0.00% |
| 10 Parana | 0.37% | 4.93% |
| 11 RSul | 0.39% | 3.22% |
| 12 MtGrSul | 0.16% | 9.97% |
| 13 MtGrosso | 0.57% | 30.13% |
| 14 GoiasDF | 0.22% | 4.25% |
| Total | 2.17% | 2.17% |

### *G. Tropical deforestation associated with the EU's imports of agricultural commodities in 2017 and their countries of origin.*




Source: Pendrill, F., Persson, M., Kastner, T., 2020. Deforestation risk embodied in production and consumption of agricultural and forestry commodities 2005-2017′ . In: Chalmers University of Technology, Senckenberg Society for Nature Research, SEI, and Ceres Inc. https://doi.org/10.5281/zenodo.4250532 CC BY 4.0.