University of São Paulo
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The European Union deforestation-free policy and the potential impacts on the Brazilian economy: the soy supply chain case

Heloiza Prazeres da Silva Stam

Dissertation presented to obtain the degree of Master in Science. Area: Applied Economics

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Food Engineering

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RESUMO

A política livre de desmatamento da União Europeia e os potenciais impactos à economia brasileira: o caso da cadeia de abastecimento de soja

A União Europeia implementou uma lei pioneira que visa garantir cadeias de abastecimento livres de desmatamento para várias commodities. Este artigo explora as implicações desta política na cadeia de fornecimento de soja brasileira, examinando perspectivas contrastantes de associações industriais e organizações ambientais. O objetivo é estimar o impacto econômico do Regulamento Livre de Desmatamento da União Europeia (EUDR), utilizando um modelo de Equilíbrio Geral Computável multirregional para analisar as variações entre as regiões brasileiras e mudanças no uso da terra. Um modelo dinâmico foi utilizado para simular o impacto na economia brasileira até 2030. Sem a lista de classificação de risco divulgada, três cenários de política são simulados. Estes cenários são comparados com a projeção de linha de base, que reflete tendências históricas. O Cenário Político 1 (1AMZN) aumenta os custos apenas nas regiões pertencentes ao bioma Amazônia, o Cenário 2 (2AMZCER) semelhante a um, mas inclui regiões não apenas do bioma Amazônia mas também do bioma Cerrado, e o Cenário 3 (3ALL) para todas as regiões que exportam para a União Europeia. O objetivo é destacar o efeito da EUDR no crescimento econômico brasileiro sob diferentes classificações de risco. Os resultados mostraram um impacto multifacetado na economia e nas emissões brasileiras. As principais conclusões incluem uma potencial redução do desmatamento, alinhada com os objetivos do regulamento, mas com um pequeno impacto negativo no PIB nacional e desvalorização monetária. As famílias da classe média podem enfrentar uma capacidade de consumo reduzida devido a reduções salariais, levantando preocupações sobre a sua qualidade de vida geral. A pesquisa indica uma mudança no cultivo para culturas alternativas, como café, milho, laranja, arroz e trigo, como substitutos viáveis para a soja, mas não compensa completamente a redução da produção e exportação da soja. Regionalmente, o impacto varia, sendo esperado que Mato Grosso e Rondônia sejam os mais afetados negativamente agravando a desigualdade econômica regional. Embora se projete que as emissões diminuam na maioria das regiões, Mato Grosso, Rondônia, MaToPi e ParaAP podem experimentar um aumento devido às emissões de pastagens provenientes da pecuária, uma alternativa à produção de soja. Os resultados apontam para perdas economicas nas regiões do MaToPi e Bahia, áreas com maior produção agrícola e áreas florestais substanciais. O impacto aumentou progressivamente de 1AMZN para 2AMZCER e 3ALL, porém os cenários 2AMZCER e 3ALL tiveram valores semelhantes com diferenças sutis que indicam que a inclusão do bioma Cerrado teria o mesmo efeito que classificar todo o país como de alto risco.

Palavras-chave: EUDR, Uso da terra, CGE, Desmatamento, Soja

ABSTRACT

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

The European Union implemented 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 Computable General Equilibrium 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 the disclosed risk classification list, three policy scenarios 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 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 soybean production and exports. 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: EUDR, Land use, CGE, Deforestation, 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) create a risk classification per producing countries, which is being called benchmark system. 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 addition of other biomes; the inclusion of the financial sector; the expansion of the list of covered commodities and derived products; and the assessment of other issues, such as 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 Council and European Parliament to prevent any negative impact on supply chains 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 the majority of 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 aside from 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 shared logistics infrastructure of larger ports and significant cost increases.

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, 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. The Amazon Soy Moratorium established the rule of not acquiring soy produced in deforested areas in the Amazon biome since 2008. Now 15 years since the original agreement, 98% of the soy cultivation in the biome is in compliant areas, and only 5% of associated companies have 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, as the current second-largest exporting nation of soybean meal in the world there is an open question of what will happen to the 50% of its national export of soybean meal, which goes to the European market, worth the equivalent of $20 billion per year, how the agricultural industry will adapt, and whether the new regulations will ultimately result in land use changes that improve or worsen deforestation.

1.1. Objective

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 soy supply chain, as well as any resulting changes in land use. The impact will not be uniform, as various different regions of Brazil produce soy products at different rates, and the amount divided between internal and external consumption differs as well. Thus to evaluate the results in an aggregated and regional manner, a multiregional CGE (Computable General Equilibrium) model will be used to analyze the regional impacts to various shocks over time. What is certain is that the increased fiscalization of the supply chain will increase costs, and the model will run three scenarios for increased scrutiny (ie. costs) for export into the EU.

The specific objectives of this work include discovering whether there will be a reduction and at what level in exports of soy products from Brazil, and how it will affect the economy of the Brazilian states, and which will be most impacted economically. The model will also analyze changes in land use patterns, whether soy farms will change 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. The model will also be able to estimate any increase or reduction in carbon emissions, an important factor in the justification for implementing the EUDR.

This research also aims to fill a gap in the existing literature, which has limited studies on the regulation of deforestation-free production chains with emphasis on economic analysis.

2. POLICY BACKGROUND

2.1. Requirements of EUDR regulation

The new EU legislation on the trade of deforestation-free commodities (EUDR) (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2023) has potential to directly impacts the export of soybeans and soybean meal from Brazil. Exporting companies will be required to ensure transparency and physical segregation of the product throughout the entire supply chain, from soybean harvesting to loading onto ships.

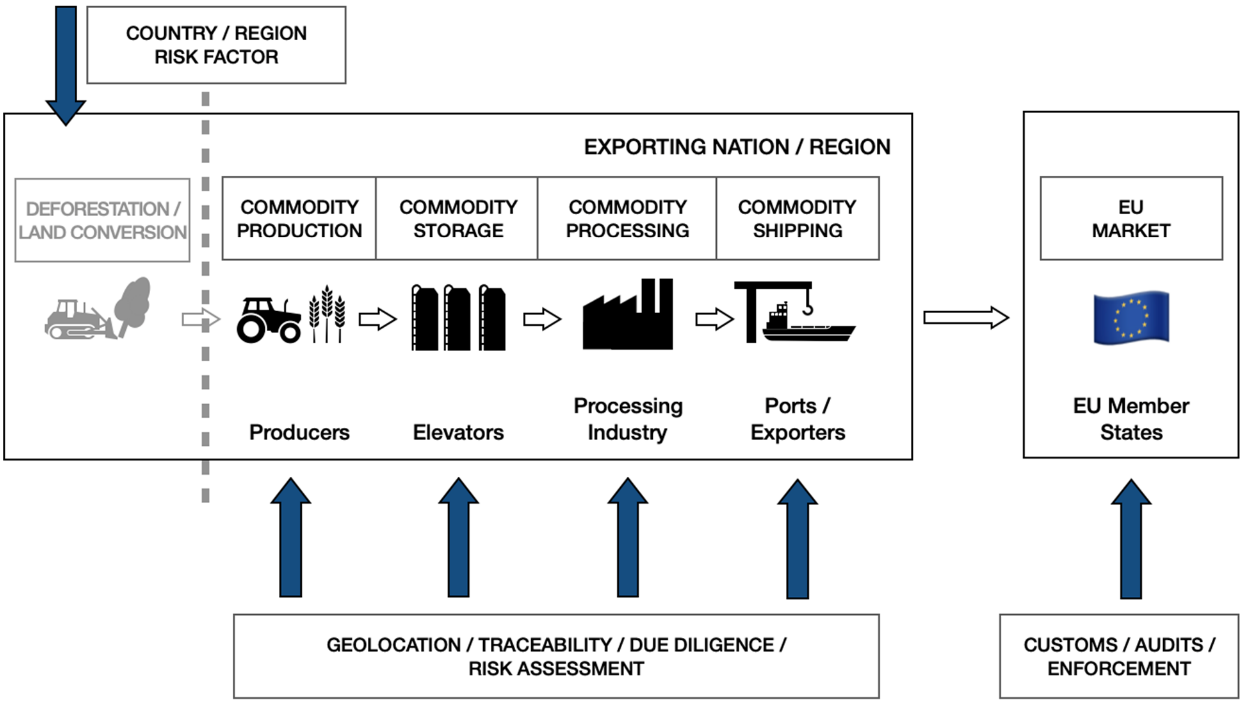

Figure. 1 The scope of the EUDR in placing controls aimed at eliminating commodities produced on deforested land from reaching the EU market.
Source: Elaborated by the author

The legislation compels companies to modify their management by implementing due diligence systems that must (i) trace the origin of soybeans, (ii) do data analysis, and (iii) perform risk mitigation. The latter two points will only be required from importers and exporters trading products from a "high-risk" country according to the EU. To classify 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. The decisions on the risk factor, and whether to apply that risk factor to the whole country or just by region has not been disclosed yet. 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 inclusion of non-forest ecosystems (Other wooded lands), such as the major part of the Cerrado biome, is scheduled to be disclosed in July 2024, and whether or not to include the Pantanal and Pampas biomes, the other soy-producing regions in Brazil, will be determined in June 2025. Companies will need to be aware of the risk classification for their operations, as it will impact costs.

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. 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. Companies operating in "low-risk" areas will only need to submit this Declaration document. Companies located in "high-risk" areas however will need to submit the Declaration and provide 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 defined in national legal systems 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.

2.2. Impact assessment of the EUDR 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 that an increased demand for these commodities and derived products originating 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. The report expressed concern that small and medium-sized enterprises (SMEs) and small producers may be disproportionately affected by the additional requirements and may not have the resources needed to comply. At the end of the chain, European consumers may face a minimal increase in product prices as the additional costs imposed on producers tend to be passed on to operators and traders.

The Impact Assessment explains that the estimation of launch and recurring costs of due diligence systems presents uncertainties and limitations, depending on the size and complexity of the supply chain. There are one-off costs to launch the necessary systems and staff to perform the analysis, and recurring costs to maintain the system. The most comparable system was the due diligence of the EUTR, 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 assessment then estimates that the recurrent costs of due diligence for the soy supply chain should fall between the range of 32 to 479 million EUR, based on a 5-year average (2015-2019) of the import value. It should be noted that the document applies the same range for all commodities, and that some supply chains may be more complex than the timber supply chain. The assessment does not mention the impact on costs on physical segregation, which are a more difficult problem in the soy supply chain.

2.3. Geocoding information

Demanding the geographical coordinates of the land plot or farm where the commodities or derived products were produced allows for the use of satellite imagery positioning to verify whether the land plot or farm were recently forests. Ground and satellite monitoring is a field-tested combination that has proven in the past to be capable of containing deforestation in a given area and is expected to enhance the effectiveness of policy interventions, 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). The cut-off date for determining non-deforested areas in regard to the EUDR was Dec. 31st, 2020. Any commodity production geolocated to land classified as forest on that date 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 who may not have such a system in place.

3. LITERATURE REVIEW

3.1. Soy supply chain overview

Soybeans are a highly versatile and globally traded commodity, and can be sold as soybeans, soybean oil or soybean meal. Soy 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 a leading source of soy products to the EU, responsible for 39% of EU imports from 2015-2019 (EUROPEAN COMMISSION, 2021a). The soy supply chain involves various different actors involved in the harvesting, threshing, transportation, drying, cleaning, grading, packaging, storage, and processing of soy products (ISLAS-RUBIO et al., 2002), as described below.

3.1.1. 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. Machineries are commonly used for soybean crop harvesting. After harvest, soybeans can be stored on the farm before being sold or directly sent to silos and warehouses (THAKUR; DONNELLY, 2010).

3.1.2. Elevators

This is a very important link between the producer and the processing industry. Because they buy soybeans from farmers, store them, and mix 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. Therefore, a specific batch sent to the processor may contain soybeans from all sources that may end up in the finished product (THAKUR; DONNELLY, 2010). According to EUDR’s requirements the Elevators need 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. Consequently, not all elevators are able to segregate products within a facility (at least without additional investment) (BULLOCK; DESQUILBET, 2002).

3.1.3. 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 to processing soybeans from recently non-deforested areas implies a loss of efficiency and additional costs for processors (BULLOCK; DESQUILBET, 2002).

3.1.4. Port terminals

The export storages have a physical layout similar to rural elevators, but on a much larger scale. 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. 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).

3.2. Certification and traceability systems

Deforestation-free soy is an example of a product that has a credible quality. This is because credible qualities are difficult for consumers to evaluate, even after purchase and consumption (DARBY; KARNI, 1973). Unlike the non-GMO status of soybeans, the deforestation-free attribute is intangible and cannot be verified through laboratory examination (LIPPERT, 2009). To address this, traceability systems are used to track the product throughout the supply chain and confirm its authenticity, quality and safety. This is necessary to ensure deforestation-free production.

Certification is used as a common proxy for eliminating deforestation from supply chains, and in this context, traceability systems are often referred to as Chain of Custody (CC) systems (ISEAL ALLIANCE, 2016). In the figure below, we have four forms of CC systems for agricultural supply chains, visualized in descending order according to the level of traceability: identity preservation, segregation, mass balance, book and claim (HINKES; PETER, 2020; ISEAL ALLIANCE, 2016). Soy certified as identity preserved or segregated is physically kept separate from non-certified soy throughout the supply chain. In contrast to identity preservation, segregation allows for the mixing of certified soy from different 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 is an approach that facilitates the trading of certificates independently from certified products (HINKES; PETER, 2020). The EUDR does not specify which form of custody chain the commodities in question will need to follow; however, industrial associations and NGOs have interpreted that the requirements fit a segregation chain of custody.

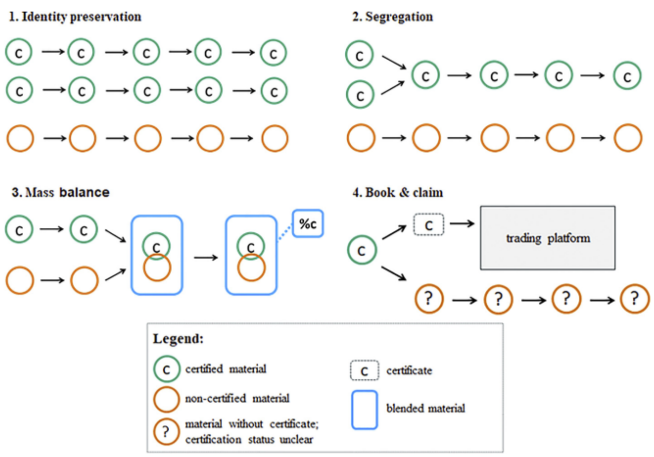

Figure 2 – Common types of custody chain systems

Source: Hinkes e Peter (2020)

In the global soy supply chain, there are multiple co-existing certification systems (MOL; OOSTERVEER, 2015), and Brazil has a high adoption of certification, especially compared to other South American soybean producers. This has contributed to a competitive advantage in trading with European countries, along with the continued production of non-genetically modified soybeans (GARRETT; RUEDA; LAMBIN, 2013). A report from FEFAC says that approximately 25% of EU27+ (European, UK, Norwegian, and Swiss) soy was certified deforestation-free in 2020 (IDH, 2022). This indicates that the current numbers are far from the EU's expectation of 100% deforestation-free.

Commitments to end deforestation from companies using or producing soybeans are rare based on a worldwide survey (CDP, 2021). One important driver for companies to get deforestation certification is to maintain external market and improve reputation, especially when the country's environmental performance is unfavorable (HALALISAN et al., 2019). Companies need to evaluate economic advantages against the additional costs required to maintain the traceability system. This trade-off can be more advantageous with the certification system of Book and Claim, as it provides monetary value and can be traded. However, there is criticism that the Book and Claim system is vulnerable to fraud and public mistrust (MOL; OOSTERVEER, 2015). The book and claim system have the largest market share of certified products in the soy supply chain.

One example of Book and Claim is the REDD Credits, which are symbolic tokens of reducing emissions from deforestation and forest degradation in developing countries. Rosa et al. (2023) conducted a policy simulation in which REDD credits were traded in an international carbon market. The results indicated that REDD may not be sufficient to foster developing countries' participation in climate policy. This trend is also reported in IDH (2022), which highlights the lack of mainstream adoption of certified soy in the EU27+. Another unfavorable fact is inefficiency, as certification will very likely fall short in preventing degradation of tropical forestry, particularly in politically and economically unstable situations (LIPPERT, 2009).

3.3. Environmental policies

An increasingly promising avenue is found in the realm of environmental policies. These policies have the potential to induce change either through direct regulation of domestic economic activities or by restrictions on trade from high risk supplier locations Examples include taxation of carbon, the prohibiton of trade involving illegal harvested timber, or the implementation of the Carbon Border Adjustment Mechanism (CBAM).

These regulations triggered the widespread 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).

Domestic carbon tax is one of the main policy tools for reducing local emissions. Lin and Jia (2018) have reported its impact in China and demonstrated that the effect on GDP is negative but small. The key lies in balancing the negative effects on GDP and other macroeconomic indicators (ABEL et al., 2023). Regardless, relying only on countries initiatives is troubling as numerical simulations have shown that countries have to be more ambitious on their actions to curb GHG emissions in order to achieve significant outcomes (BÖHRINGER; HELM; SCHÜRER, 2023)

On the international trade policies concerned with deforestation an example is the restriction on the sale of illegally harvested wood in consumer countries, which has caused the market for wood products from suspicious sources to shift to unregulated markets experiencing rapid increase in demand (ROE, 2015). Sun and Bogdanski (2017) demonstrated that trade policies implemented by a few importing countries, which increase 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.

The European Union has implemented environmental trade policies beyond EUDR. One such initiative is the Carbon Border Adjustment Mechanism (CBAM), which aims to impose additional tariffs on goods imported into the EU based on their carbon emissions. The goal of CBAM is to achieve carbon parity and address the unequal position of national products in foreign trade. A case study conducted by Chen (2023) on CBAM for China reveals that carbon tariffs will reduce the price of Chinese exports, resulting in a slight decrease in China's real GDP and carbon emission intensity in the related sectors. The study also suggests that the overall impact of carbon tariffs on carbon emissions is minimal, and it concludes that CBAM is primarily a protective policy. Additionally, the study highlights limitations of carbon tariffs, as the advantage it gives to local suppliers is unsustainable, necessitating more subsidies from the EU government for these suppliers to compete with Chinese counterparts.

Another regional approach to influence climate ambitions in trading countries involves incorporating environmental requirements into international trade agreements. These agreements transcend the conventional exchange of goods and services, pushing for broader objectives such as environmental concerns, and have witnessed a consistent rise over the years. Trade agreements that enforce commitments to forest preservation have shown a modest yet significant reduction in deforestation (FRANCOIS et al., 2022).

3.4. Additional costs components

3.4.1. Segregation costs components

As the EUDR requires physical segregation of products and the impact assessment overlooked this cost increase, we investigated the cost components in the 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 are able to cover these additional expenses by receiving price premiums from buyers (KALAITZANDONAKES; LUSK; MAGNIER, 2018). Therefore, the actors from soy supply chain have an expectation of a premium price from the Euroepean Union, which has not been detailed so far. Segregating products involves the need for adaptations and changes in governance. Contracts can take various forms, depending on the characteristics of the transaction. These costs are identifiable and closely related to the transaction characteristics and attributes of the product to be segregated (SOUSA, 2020).

In the soy supply chain, farmers are consistently 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. For example, additional elevator segregation costs should include 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: costs of reducing information asymmetry and liability. The chances of verification proving that a submitted shipment is non-compliant are lower if the seller commits to segregation practices in a contract. Early contracting also allows the buyer to plan volumes and flows.

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 at a later date 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).

3.4.2. Due diligence system costs components

Due diligence is an on-going proactive and reactive process whereby enterprises take reasonable steps and make good faith efforts to identify and respond to risks(“Quantifying the Costs, Benefits and Risks of Due Diligence for Responsible Business Conduct Framework and Assessment Tool for Companies”, 2016). To comply with EUDR companies need a due diligence system yet only 17% of soybeans companies have a comprehensive risk assessment and 10% implemented high levels of traceability to municipality level (CDP, 2021).

To implement a due diligence system, spending on several key areas is imperative. Changes to corporate compliance policies and supply chain operating procedures necessitate dedicating resources to staff time, consultant fees, and training to ensure a seamless transition. The establishment of essential IT systems is a crucial component, encompassing procurement, installation, and ongoing support. Data collection and verification require investment in both staff time and consultant fees. Audits, a key part of the process, involve fees paid to third parties for comprehensive assessments. First-year costs involve setting up necessary structures, including personnel and IT systems, and organizing meetings and training sessions for staff. Annual costs are incurred for the ongoing tasks of carrying out due diligence and reporting.

4. METHODOLOGY

4.1. TERM-BR model

TERM, also known as The Enormous Regional Model, is a multiregional CGE model that focuses on analyzing the regional impacts for various shocks. This model treats each region within a single country as a separate economy, allowing for detailed examination of region-specific characteristics. TERM is particularly suitable for large countries with numerous 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 specific version that incorporates annual recursive dynamics and offers a detailed bottom-up representation of regions in Brazil. The dynamic version is composed of 122 sectors (industries), 122 commodities and 27 regions. These regions are represented by 27 interdependent models, representing the 26 states and the Federal District, 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, throughout the specified years. This transition matrix is employed to project the deforestation rate or the increase in total land supply (DOS SANTOS; DE OLIVEIRA; FILHO, 2021).

4.2. Database

In regional CGE modeling, 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 have 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 released by the Brazilian Institute of Geography and Statistics (IBGE). This matrix provides valuable insights into the interdependencies of sectors within the economy. To supplement this data, 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) are utilized.

To ensure the model's relevance and accuracy, the database was updated with historical data up to the year 2022 to reflect the current economic landscape and then projections were made 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 and are deflated by the GDP deflator. These prices are sourced from reputable institutions such as the International Monetary Fund (IMF), Food and Agriculture Organization (FAO), and World Bank.

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

4.3. Aggregating the TERM-BR model

For this study, the model was aggregated at the level of 14 regions (see Figure 3), 39 commodities and 39 sectors (industries). The model also distinguishes 3 types of factors of production (labor, capital and land), 10 types of labor occupations in each region and 2 types of margins (trade and transport) (DOS SANTOS; DE OLIVEIRA; FILHO, 2021). The model was used to construct a base forecast for future states 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.

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

4.4. Shock estimation

There are two components needed to determine the adequate shock to the Brazilian economy in this context; the increase in cost to comply with the EUDR's more stringent regulations, and the share of soy exports from each state heading to the EU, since soy used for national consumption or for export to non-EU countries, ie. China would not be affected. The cost increase was calculated from a test run by Pires[1] in partnership with Menthonnex[2], designed to ensure traceability and transparency. The test consisted of filling a ship at the Port of Santos with 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 costs for segregation, tracking, and due diligence resulted in an additional cost of €30/ton. If the region is considered "high-risk" an additional €2/ton for deforestation and conversion risk assesment was estimated by the Earthworm Foundation. There are other possible factors that could influence the additional costs, but based on the current price of soybeans, the increased costs of €32/ton represent a price increase of 6% per ton of the CBOT from April 2022 to April 2023 and is a reasonable representation of the change in price for exporting under the EUDR.

To determine the share of soy product sent to the EU by region data was obtained from Trase (TRANSPARENCY FOR SUSTAINABLE ECONOMIES (TRASE), 2018), a data-driven

[1] Pires, Bernardo. (Abiove). Information received by email. 2023.
[2] Menthonnex, Daphné. (Earthworm Foundation). Information received by email.2023.

initiative that provides transparency in the international trade and financing of commodities associated with tropical deforestation, founded by the Stockholm Environment Institute and Global Canopy at COP 21. Trase has developed a comprehensive database specifically designed to track the soybean supply chain in Brazil and evaluate its links to deforestation. Then, integrates data from sources like Comex Stat to access commercial records per vessel, information from ABIOVE, CONAB, and CGC MAPA to provide valuable insights on crushing and storage facilities, locations, capacities, export authorizations, transportation costs, and data from soybean-producing municipalities obtained from SIDRA IBGE. By combining all this data and utilizing the Supply Chain Mapping Method (SEI-PCS), intricate networks and practices involved in the soybean trade was uncovered. The approach considers "equivalent soybean" shipments measures, a standardized estimate which takes into account both soybeans and soymeal based on mass balance calculations. The data used for this analysis is based on the years 2019 and 2020, as there were different commercial data sources and methods used for the years 2004-2018. The years 2019-2020 are the most recent and relevant data and make a good proxy for the current share of exports to the EU.

Table 1 relates the value of the traded soy product in US dollars as it flows along the supply chain to all countries and to the EU. These values are based on the shipment at the port of export, known as the freight on board value or FOB. The table displays the distribution of soybean exports from different states in Brazil to the European Union. Among the states listed, Rondonia contributes the largest share with 66% of its soybeans being sent to the EU. On the other hand, São Paulo has the lowest contribution, with only 5% of its soybeans being exported to the EU. These export share to the EU 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.

The total shock to each state would only reach a maximum value of 6% cost increase in the case that all of its soy was exported to the EU. This is the maximum incremental cost that mulplied by the share export to EU of equivalent soy determines the shock per Federal unit, this is the ratio calculation method. For example, the share of exports to the EU in Rondonia is 66%, so 66% of the maximum incremental cost of 6% per ton gives an estimated shock to the cost of soy production for Rondonia is 4%. Likewise, 31% of the maximal incremental cost of 6% gives an estimated shock of 1.8% for Bahia.

The cost increase shock was implemented through 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, this cost will be equivalent to a tax increase. Considering the aggregated size of the shocks, which are small compared to the size of the economy, no recycling mechanism for this extra tax collection was considered.

Table 2 shows the estimated shock for every soy producing federal unit and lists them in descending order.

Table 2 – Shoch values for the producing federal units (%)

Federal Units	Share of equivalent soy export to EU	Maximum incremental cost	Shock
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.

4.5. Model closure

The closure of the model is based on the work of (DE SOUZA FERREIRA FILHO; RIBERA; HORRIDGE, 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. This ensures 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) regional household consumption is linked to regional wage income and to national household consumption; (v) 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[3] are endogenous and determined by the transition matrix. And, for the policy scenarios there is conversion of unused land in the land-constrained regions, and land moves endogenously between Crop, Pasture, and Plantation Forest uses.

4.6. Simulation strategy

In a dynamic model, the first step for a simulation is to build a baseline (trend, or business as usual scenario) for the economy, to which the policy scenarios will be compared. The simulation proposed in this study will compare the baseline of the projected Brazilian economy up to 2030 to the impacts observed on the Brazilian economy up to 2030 under the EUDR regulation. Since the EU haven't disclosed the risk classification list yet we will run 3 policy scenarios that simulates different possibilities of classification of risk. We compare these 3 policy simulations with the baseline to highlight the effect of EUDR restrictions on Brazilian economic growth. 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.

Policy Scenario 1 (1AMZN): where there will be an increase in costs only for the regions of the Amazon Biome as they are considered high risk of deforestation areas.

Policy Scenario 2 (2AMZCER): where there will be an increase in costs in the regions of the Amazon and Cerrado Biomes because they are considered high deforestation risk areas.

Policy Scenario 3 (3ALL): where there will be an increase in costs for all regions that export to the European Union.

The cost increases will be implemented in the model through increases in the rate of production taxes. Considering the size of the shocks, which generate very small extra taxes collection when compared to the total tax in the economy, no tax revenue recicling is implemented. The regions involved in each scenario can be seen in Table 3, below.

[3] Rondonia, AmazACRR, ParaAP, Bahia, MaToPi, MinasG RSul, MtGrSul, MtGrosso, GoiasDF.

Table 3 – Value of shocks to Model's regions under each Policy. Percent change in the rate of taxes on production.

State of Brazil (UF)	**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.

5. RESULTS

5.1. 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 and real government consumption are almost unnoticed. However, there will be a negative effect of 0.001% for the first and third scenario on family's expenditure. And the same value can be observed on the public expenditure for the most retrisctive scenario. Therefore, there was no significant impact on GDP, consumers, and government consumption at the aggregate level.

There are greater 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 substantially 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 oscilated positevily 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. Overall, with alternative crops failling 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 compensante exports is chalenging.

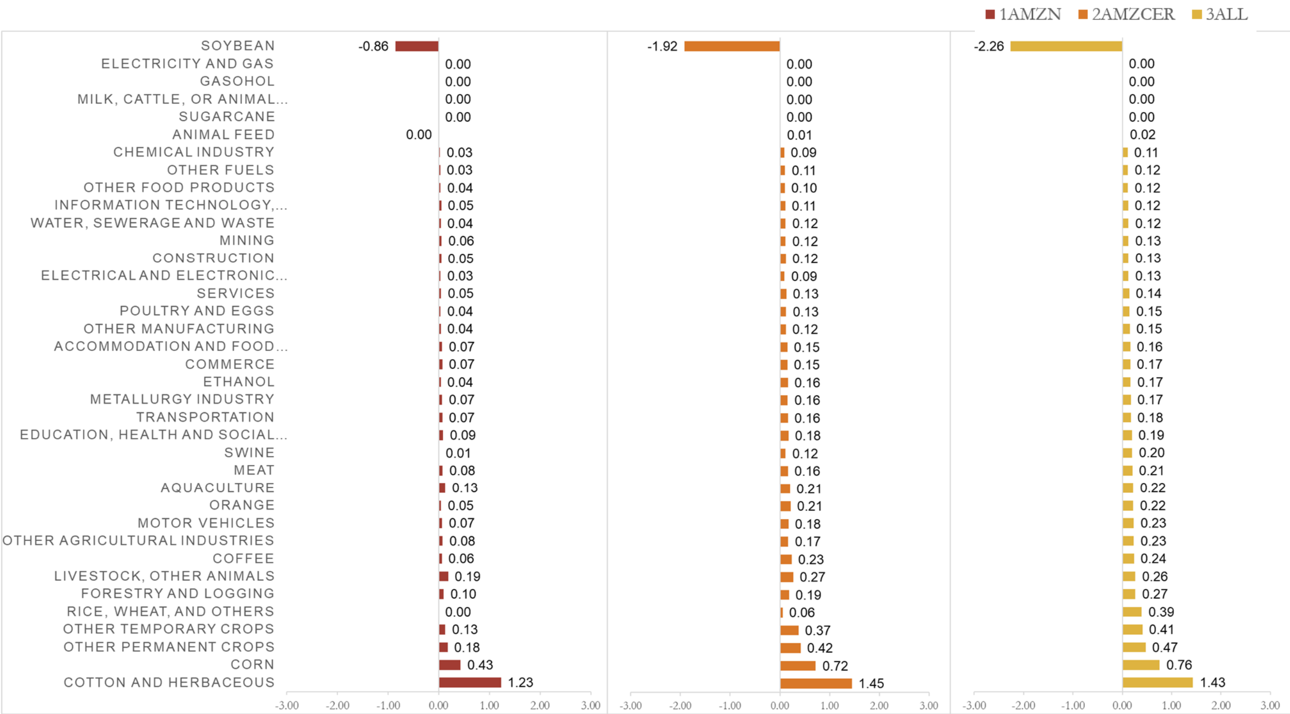

Figure 4 – Model results for national exports volume (% change from 2023 to 2030)
Source: Elaborated by the author.

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 agricultural workers.

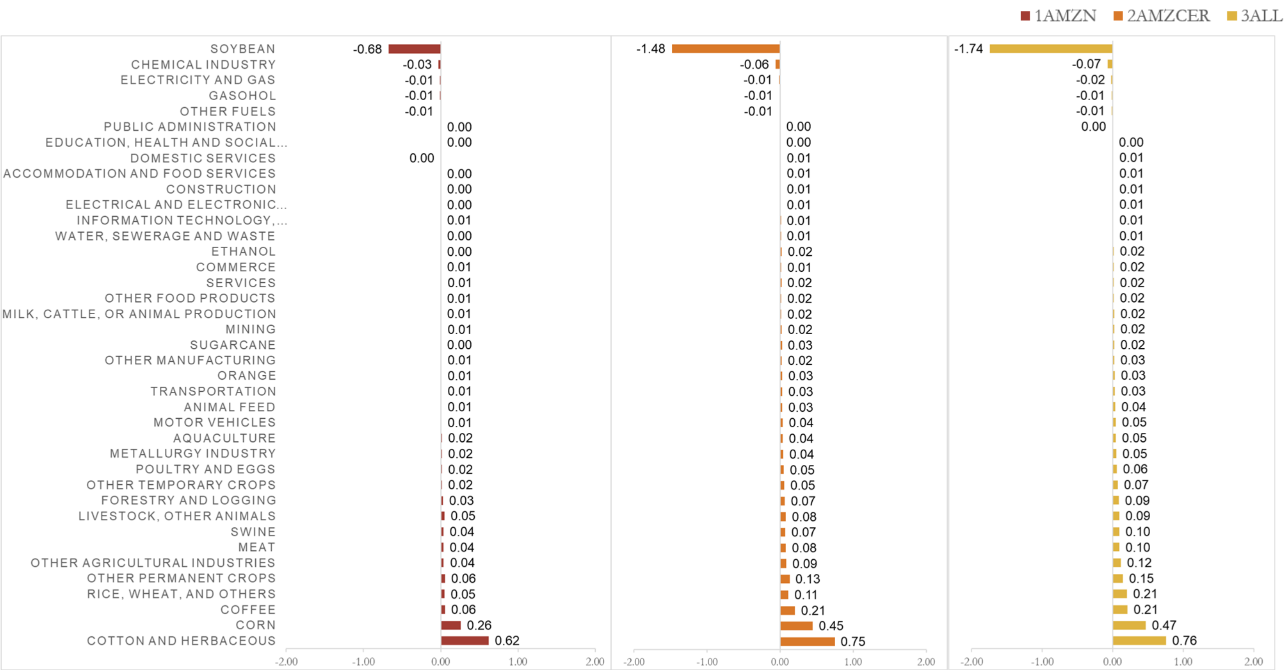

Figure 5 – Effect in the industry outputs nationally (% change from 2023 to 2030)

Source: Elaborated by the author.

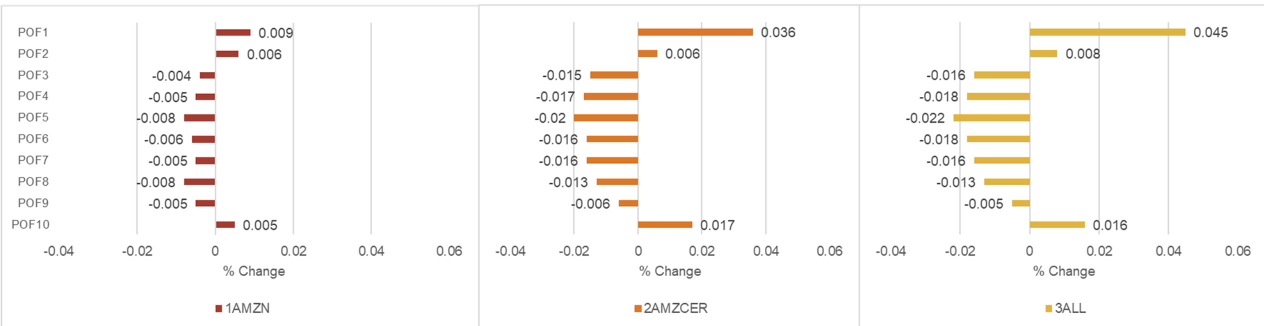

Figure 6 – Effect in the total real household consumption nationally (% change from 2023 to 2030)

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 cases the highest wages are relatively unaffected.

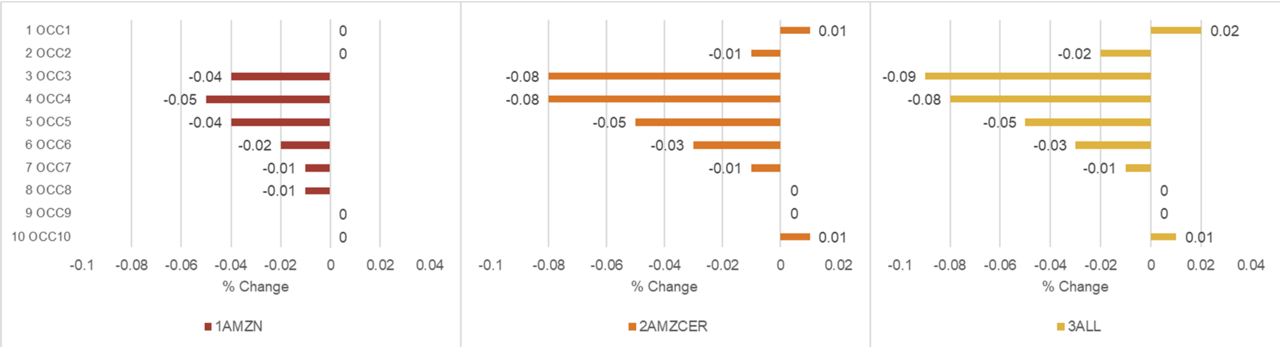

Figure 7 – Total wage bill (% change from 2023 to 2030)

Source: Elaborated by the author.

5.2. 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. In scenario 1, we see that the GDP loss is heavily concentrated into the regions MtGrosso, Rondonia and MaToPi. This makes sense as Mato Grosso is by far the largest state when it comes to soy production, so even if a lesser percentage is exported to the EU, it is still a significant volume. Rondonia has a much smaller soy production, but much more of it is send to the EU, so it will be disproportionally affected by the policy. 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 as a consequence 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.

Figure 8 – Real GDP per region (% change from 2023 to 2030)

Source: Elaborated by the author.

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 also face contractions in household consumption. The areas least affected are those less dependent on the soy trade today.

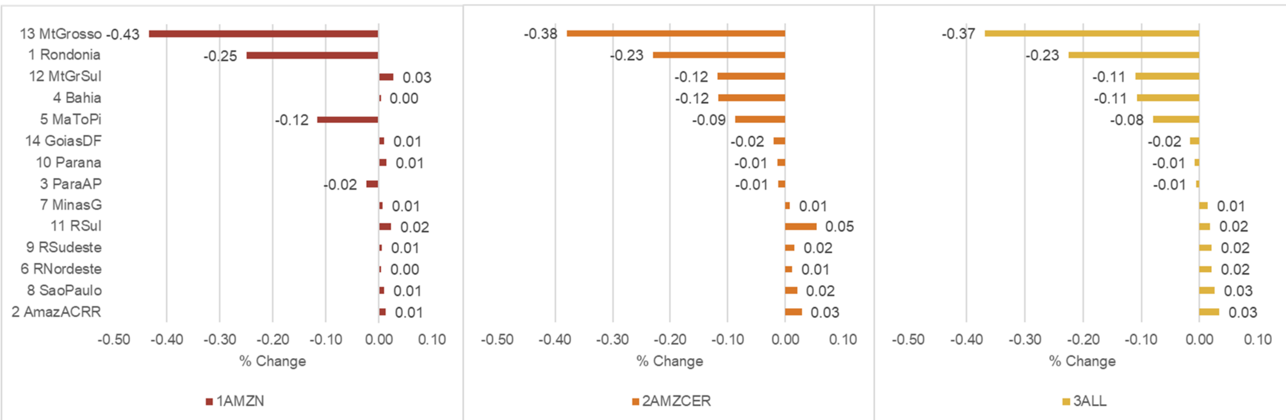

Figure 9 – Real Household consunption per region (% change from 2023 to 2030)

Source: Elaborated by the author.

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. Even though the first scenarios have more positive percent changes regionally, which may lead to a positive overall number nationally, this is not the case.

Figure 10 – Model results for exports volume regionally (% change from 2023 to 2030)

Source: Elaborated by the author.

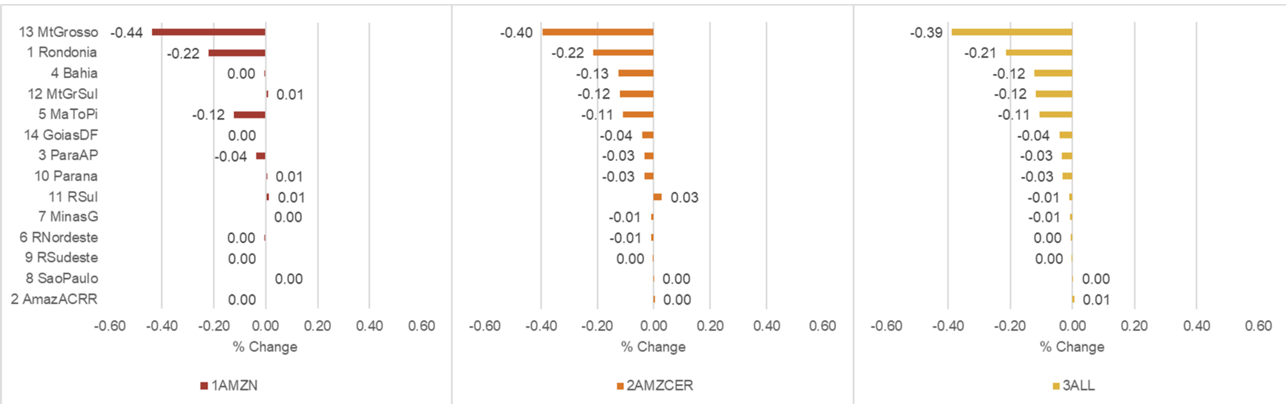

Figure 11 – Model results for real wage regionally (% change from 2023 to 2030)

Source: Elaborated by the author.

The increase in exports of MtGrosso and Rondonia was not associated with labor-intensive industries, thats 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.

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.

5.3. Emissions analysis

In an attempt to clear their soybean supply chain from products originating from deforestation, the impact of the EU measures could reduce deforastation in Brazil and potentially reduce national greenhouse gas (GHG) emissions. Figure 13 illustrates changes to national total emissions from different emitting sources. In scenario 1, we observe a decrease at all emitting sources of GHG except Mining. There is a total decrease of 0.070 in this setting, driven primarily by Land Use change reduced emissions. Scenarios 2 and 3 also have reduced emissions but Ethanol change direction and increase emissions.

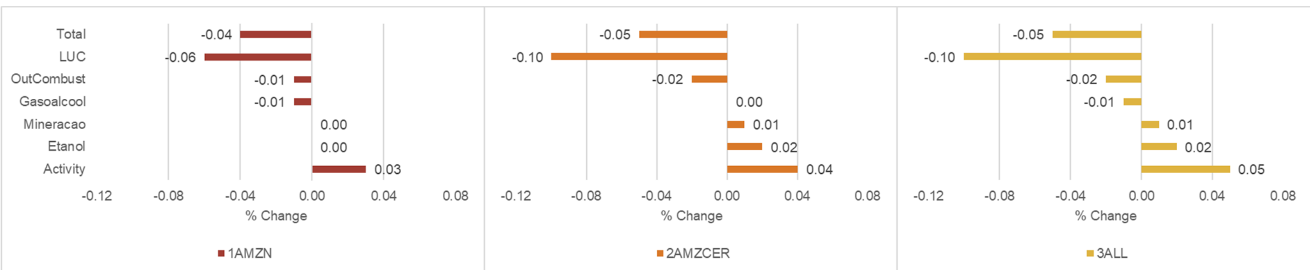

Figure 13 – Model results for total emissions by emitting source (% change from 2023 to 2030)

Source: Elaborated by the author.

Figure 14 showcases the dynamics of land use. We observe a small decrease of 0.05, 0.102, and 0.108 in crop utilization, accompanied by a rise of 0.043, 0.086, and 0.102 in pasture area, respectively, for each scenario. Unused (natural forests) shows positive values in all scenarios, indicating a reduction in deforestation (0.006, 0.010, and 0.009). This demonstrates that in every scenario, there is a decrease in the amount of land dedicated to crops and a slight increase in unused land, which means more natural forest, compared to the baseline.

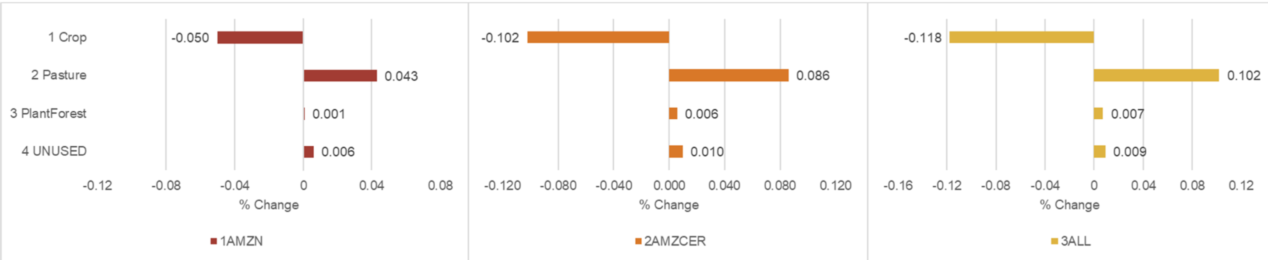

Figure 14 – Model results for National Change broad areas in hectares

Source: Elaborated by the author.

When we breakdown the impact on the regional level, we again see that the results are very region specific. Figure 15 display the shifts in total emissions regionally. The emissions are slightly reduced in 10 of the 14 regions but increased in four. MtGrosso, Rondonia, MaToPi and ParaAP will increase emissions across all scenarios, this happens because the emissions in land use change in pasture (with the correspondent increase in herd size) will increase more than the reduction from deforestation. And ranching is the biggest emitter in agriculture emissions due to emissions in livestock digestion. MtGrSul, Bahia, Parana and GoiasDF will decrease emission in the first scenario and increase in the other two policies. And again, here the same reason is the increase in land use change in pasture. RSudeste won't be affected. MinasG, RNordeste, SaoPaulo, AmazACRR will decrease emission regardless of the scenarios they are in.

The EUDR should be effective in reducing deforestation, however the increase in emissions from the targeted regions due to pastures is noteworthy. The regulation also includes cattle in the controlled commodities, still this should not be able to curb emissions from ranching as the majority of beef produced in Brazil is consumed domestically.

Figure 15 – Total emissions regionally (% change)

Source: Elaborated by the author.

Figure 16 examines the changes in the Unused areas (Natural Forest) across different regions. It is evident that in scenario 1, the increase in forested areas is limited to the MinasG, Bahia, and particularly MaToPi regions. Conversely, MtGrosso and Rondonia experience slight decreases in forested areas, whereas the other regions remain relatively stable. Scenarios 2 and 3 yield similar outcomes, with the majority of forest gains observed in MaToPi and Bahia, while MtGrosso observes the highest losses in forested areas. The remaining regions either exhibit minor changes or no change at all. In summary, the alteration in native forests displays an overall positive trend.

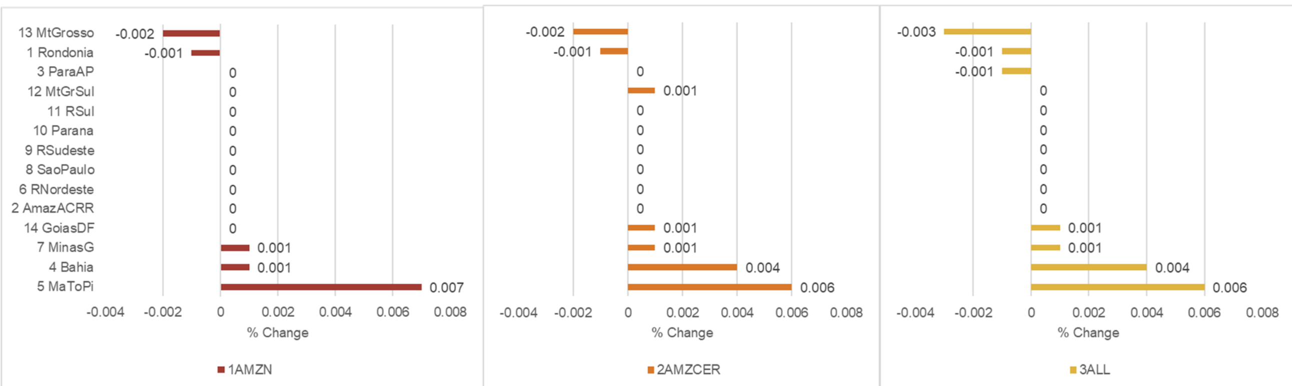

Figure 16 – Change in Natural Forests areas, million of hectares (c) regionally

Source: Elaborated by the author.

6. 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.

Particularly, middle-class households may experience a dip in their consumption capacity due to the reduction in wages. Economically, this is cause for concern as it could lead to a decrease in the overall quality of life for these households and require appropriate action from federal and regional policy makers.

In consideration of the country's agricultural production, there is evidence to suggest a shift in cultivation, with crops 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 substitution 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 in pasture emissions as ranching is 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 São 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. Future research could carve out a path for such solutions while continuing the essential work of tracking these intricate dynamics.

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APPENDIX

Appendix A. Value of shocks to States under each Policy

State of Brazil (UF)	**1AMZN Shock**	**2AMZCER Shock**	**3ALL Shock**
Rondonia	4.0%	4.0%	4.0%
Para	1.8%	1.8%	1.8%
Mato Grosso	1.0%	1.0%	1.0%
Maranhão	0.8%	0.8%	0.8%
Tocantins	0.7%	0.7%	0.7%
Bahia		1.5%	1.5%
Mato Grosso do Sul		0.9%	0.9%
Piaui		0.8%	0.8%
Goias		0.7%	0.7%
Parana		0.7%	0.7%
Minas Gerais		0.5%	0.5%
São Paulo		0.3%	0.3%
Santa Catarina			0.8%
Rio Grande do Sul			0.5%

Source: Elaborated by the author.