EUDR and Deforestation in Brazil: Are Producers Anticipating the European Deforestation-Free Regulation?

Alan Leal*
Ana Flávia Trevizan†
Michelle Marcia Viana Martins‡
Carmen Fonseca§

Abstract
The European Union Deforestation-Free Regulation (EUDR, Regulation (EU) 2023/1115 of the European Parliament and of the Council of 31 May 2023) is set to enter into force in early 2027, after two postponements. This regulation was enacted in July 2023 and aims to reduce the deforestation footprint of the EU for a given selection of goods: soya, coffee, cattle, rubber, cocoa, wood, and palm oil, along with their derived products. Although the regulation's effects have yet to become legally binding, its impacts on deforestation and land use should occur earlier, given that it prohibits EU countries from importing these goods if produced on land deforested or degraded after December 2020. In this context, this paper analyzes, from legal and economic perspectives, whether preceding and anticipatory effects, respectively, of this regulation exist, focusing on deforestation and land use in Brazil. We deploy an impact analysis, anchored by a legal analysis, that measures the EUDR's impact on deforestation and land use patterns. Our model employs novel data on municipalities' production directed toward exports, singling out exports of selected goods to the EU. These novel data and methods allow for conclusions indicating that the EUDR has not yet produced any identifiable effect on deforestation or land use.

Keywords: Impact analysis; international trade; precedential effects; anticipatory effects; environment.

Resumo
O Regulamento da União Europeia para Produtos Livres de Desmatamento (EUDR, Regulamento (UE) 2023/1115 do Parlamento Europeu e do Conselho, de 31 de maio de 2023) deverá entrar em vigor no início de 2027, após dois adiamentos. Esse regulamento foi promulgado em julho de 2023 e busca reduzir a pegada de desmatamento da União Europeia associada a uma seleção específica de bens: soja, café, gado, borracha, cacau, madeira e óleo de palma, além de seus produtos derivados. Embora os efeitos do regulamento ainda não tenham se tornado juridicamente vinculantes, seus impactos sobre o desmatamento e o uso da terra deveriam ocorrer anteriormente, uma vez que ele proíbe os países da União Europeia de importar esses bens quando produzidos em terras desmatadas ou degradadas após dezembro de 2020. Nesse contexto, este artigo analisa, a partir das perspectivas jurídica e econômica, respectivamente, se existem efeitos precedentes e antecipatórios desse regulamento, com foco no desmatamento e no uso da terra no Brasil. Para tanto, empregamos uma análise de impacto, ancorada em uma análise jurídica, que mensura o impacto da EUDR sobre os padrões de desmatamento e uso da terra. Nosso modelo utiliza dados inéditos sobre a produção municipal destinada às exportações, distinguindo especificamente as exportações dos bens selecionados para a União Europeia. Esses novos dados e métodos permitem concluir que a EUDR ainda não produziu qualquer efeito identificável sobre o desmatamento ou o uso da terra.

Palavras-chave: Análise de impacto; comércio internacional; efeitos precedentes; efeitos antecipatórios; meio ambiente.
Classificação JEL: Q23; Q18; F13.
Área da ANPEC: Economia Internacional.

*Ph.D. in Economics by the University of São Paulo and Associate Researcher at the Fundação Getúlio Vargas Global Business Center. ORCID: https://orcid.org/0000-0002-1141-7747. Email: prof@alanleal-econ.com.

†Ph.D. in Climate Change and Sustainable Development from NOVA University Lisbon, researcher at the Rights Lab at the University of Nottingham, supported by the British Council, and environmental lawyer and consultant. ORCID: https://orcid.org/0000-0003-4365-6053. Email: ana.trevizan@nottingham.ac.uk.

‡Ph.D. in Economics by the University of São Paulo and Economics Professor at University of Viçosa. ORCID: https://orcid.org/0000-0002-0790-5625. Email: michelle.viana@ufv.br.

§Ph.D. in International Relations by the Faculdade de Ciências Sociais e Humanas (FCSH) and Assistant Professor at Instituto Português de Relações Internacionais (IPRI). ORCID: https://orcid.org/0000-0003-2797-7754. Email: carmen.fonseca@fcsh.unl.pt.

1 Introduction

Deforestation drives biodiversity loss and contributes to global greenhouse gas emissions (IPCC, 2021). The European Union (EU), as a major importer of agricultural commodities, has recognized its role in this process through consumption patterns and it has employed measures to counterbalance it. In response to its role in global deforestation, the European Parliament adopted the Regulation on Deforestation-Free Products (EUDR) on June 29, 2023, following negotiations that began in late 2021 ("Regulation (EU) 2023/1115 of the European Parliament and of the Council of 31 May 2023 on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation", 2023). The EUDR mandates that companies placing cattle, cocoa, coffee, palm oil, rubber, soy, wood products, and derived goods on the EU market must demonstrate through due diligence that these commodities were not produced on land deforested or degraded after December 31, 2020. Originally scheduled for enforcement in December 2024, implementation has been postponed twice to December 30, 2026, for large companies and June 30, 2027, for small and medium enterprises.

By conditioning EU market access on production practices abroad, the EUDR manifests the "Brussels Effect", whereby the EU leverages its market power to extend regulatory standards beyond its borders (Bradford, 2020). Unlike multilateral environmental agreements requiring negotiated consensus, the EUDR imposes extraterritorial obligations on producers in exporting countries. For Brazil, which supplies substantial volumes of soy, cattle, and coffee to European markets, the implications are direct, but a relevant dimension remains unexplored: the regulation's preceding effects.

The period between policy announcement and enforcement can trigger strategic behavioral responses. When economic agents expect future restrictions to increase costs or restrict market access, they may rationally adjust their behavior in the present (Rittenhouse & Zaragoza-Watkins, 2018). In the EUDR context, producers who deforested land after December 31, 2020, face exclusion from EU markets regardless of when the regulation is enforced. Between the regulation's announcement in 2021 and its implementation in 2027, these producers may respond strategically by redirecting exports to non-EU markets, shifting to commodities not covered by the EUDR, or expanding production in ecosystems that fall outside the regulation's definitional scope (Trevizan, Leal, & Valle, 2025; Trevizan, 2024a).

This last possibility is particularly relevant for Brazil because the EUDR's coverage hinges on a forest-based definition that does not map neatly onto the country's main agricultural frontier. Under the regulation, 'forest' follows the Food and Agriculture Organization's definition as land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover exceeding 10% ("Regulation (EU) 2023/1115 of the European Parliament and of the Council of 31 May 2023 on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation", 2023, Article 2 (4)). While this definition encompasses the Amazon rainforest, it inadequately captures the Cerrado, Brazil's tropical savanna that accounts for 40% of the country's soy production. Trase (2025) confirm that the EUDR does not apply to savannah forests defined by the FAO as "other wooded land." In Brazil, only 17% of recent soy expansion into natural habitats occurred in forested areas, with traders more likely to source soy that has encroached on the Cerrado and Pampa, which are not protected by the EUDR. This definitional gap creates a potential incentive for spatial displacement of agricultural expansion from forested biomes to non-forested biomes.

Brazil's experience with the Amazon Soy Moratorium (ASM) provides both precedential and caution. Heilmayr, Rausch, Munger, and Gibbs (2020) demonstrated that the ASM, a voluntary zero-deforestation commitment by grain traders established in 2006, reduced deforestation in soy-suitable Amazon areas by approximately 18,000 km^2 over its first decade. This success coincided with accelerated soy expansion in the Cerrado, raising concerns about leakage effects whereby conservation

policies in one region displace environmental pressures to less-protected areas (Brandão, Souza, Ribeiro, & Sales, 2025). Whether the EUDR might replicate or amplify such displacement dynamics remains an open question.

The literature on environmental regulation has documented that policy announcements can trigger behavioral adjustments before enforcement. Rittenhouse and Zaragoza-Watkins (2018) showed that the announcement of stricter emissions standards for heavy-duty vehicles in the United States led to a surge in sales of non-compliant vehicles before the standards took effect. Their findings demonstrate that anticipation can generate welfare losses by extending the lifespan of environmentally harmful capital stock. Smulders, Tsur, and Zemel (2012) documented a similar "green paradox" in climate policy, where the announcement of future carbon taxes can perversely increase emissions in the interim period as resource extractors accelerate depletion to avoid future costs. These perspectives suggest that the gap between the EUDR's announcement and enforcement creates a window for strategic behavior.

Studies on anticipatory behaviors in conservation policy are accumulating. Llopis et al. (2023) proposed a framework to compile anticipatory forest use behaviors across diverse policy contexts: landowners in Queensland, Australia, engaged in "panic clearing" of native vegetation ahead of land management regulations; in the United States, property owners destroyed endangered species habitats after species listings but before enforcement; in Madagascar, communities accelerated forest clearing before protected area establishment to secure agricultural land claims. These cases suggest that the announcement of conservation policies, particularly those involving land use restrictions, can trigger a rush to convert land before enforcement.

The EUDR's anticipatory effects may manifest differently. Because the regulation's cutoff date is retroactive to December 31, 2020, producers cannot avoid compliance by accelerating deforestation before enforcement. Instead, anticipatory effects may take the form of trade diversion, commodity substitution, or spatial displacement. Producers who deforested after the cutoff date may redirect exports from the EU to alternative markets. It is also relevant to emphasize the Brazilian Forest Code allows some type of deforestation, when the producer is complying with the appropriate levels of forest reserves. EUDR does not allow for any deforestation, causing a disconnection between this regulation and Brazilian Forest Code (Trevizan et al., 2025) They may also shift production from EUDR-covered commodities to non-covered products or expand production in ecosystems like the Cerrado that fall outside the EUDR's protective scope.

These anticipatory behaviors have received less attention in the literature but may be equally consequential for environmental outcomes. Studies on trade diversion suggest that regulations can induce shifts in export patterns. Dechezleprêtre and Sato (2017) found that environmental regulations can lead to adverse effects on trade, with firms redirecting exports to jurisdictions with less stringent standards. In the deforestation context, such trade diversion could undermine the EUDR's conservation objectives if displaced production simply shifts environmental pressures to other regions or markets. Similarly, the literature on leakage in conservation policy has documented that spatially targeted interventions can displace deforestation to unprotected areas. Miranda et al. (2019) demonstrated that land speculation, driven by expectations of future agricultural expansion and policy signals, is capitalized into land values even before actual conversion occurs. This speculative dynamic suggests that the EUDR, as a policy signal about future market access conditions, could influence land markets and conversion decisions well before formal enforcement.

Existing research lacks temporal analysis of deforestation patterns around key regulatory milestones: the proposal in November 2021, adoption in June 2023, and postponement announcements in 2024 and 2025. Although Miranda et al. (2019) and Brandão et al. (2025) document leakage between the Amazon and Cerrado, no study isolates the EUDR's role in this spatial dynamic regarding all Brazilian biomes. Brazilian biomes affected by the EUDR (Amazon and Atlantic Forests) are compared directly to non-affected biomes (Caatinga, Cerrado, Pantanal, and Pampa) in a non-discretionary manner allowing for spatial identification across several elements. In this way, we

propose causal identification strategies that exploit variation in exposure to the EUDR across municipalities and over time, with the following research question: To what extent has the EUDR generated anticipatory effects on deforestation and land use patterns in Brazil between its announcement in 2021 and the present?

Our objectives are twofold. First, we aim to analyze whether deforestation and land use patterns within Brazilian municipalities change in anticipation of the EUDR having its full legal effects. Our second goal is to explain this potential effect in legal terms. Our main hypothesis is that municipalities with higher exposure to EU markets and greater production of EUDR-covered commodities have experienced differential deforestation and land use patterns following the EUDR's announcement and adoption, as producers adjust to expected future market access restrictions. This hypothesis builds on the anticipatory behavior literature suggesting that rational economic agents adjust activities in response to policy signals about future costs or restrictions (Rittenhouse & Zaragoza-Watkins, 2018; Smulders et al., 2012).

Methodologically, we employ a continuous-dose experiment using municipal-level deforestation data from Brazil's National Institute for Space Research (INPE). We construct treatment intensity based on municipalities' export exposure to EU markets, their share of production in EUDR-covered commodities, and their historical deforestation profiles. By leveraging spatial and temporal variation in exposure to the regulation, we aim to isolate the causal effect of the EUDR announcement on deforestation and land use behaviors, distinguishing anticipatory effects from underlying trends driven by commodity prices, infrastructure development, or domestic policy changes. We test the parallel trends assumption using Wald tests. We also conduct placebo tests using pre-EUDR years to validate our identification strategy.

This research makes three contributions: (i) it provides empirical evidence on anticipatory effects of the EUDR, extending the literature on pre-emptive responses to environmental regulation to the context of international trade-related environmental measures. Unlike previous studies that focus on anticipatory clearing before policy cutoff dates, we examine anticipatory adjustments in the form of trade diversion, commodity substitution, and spatial displacement; (ii) it advances understanding of the Brussels Effect and extraterritorial environmental regulation by examining how unilateral EU policies shape land use decisions in distant geographies before enforcement. We demonstrate that the mere announcement of trade restrictions can generate behavioral responses that may undermine or complement the regulation's conservation objectives; and (iii) it informs policy design for deforestation-free supply chain regulations, particularly regarding definitional choices, implementation timelines, and the risk of unintended spatial displacement. Understanding whether the EUDR has inadvertently accelerated deforestation in non-protected ecosystems or induced trade diversion to less stringent markets is essential for refining implementation and designing complementary policies that address unintended consequences.

This paper is structured as follows. Besides this Introduction, Section 2 details how countries in the Global South are responding to the EUDR. Section 3 presents the exports imputation method, the continuous treatment model implemented empirically in this paper, and the sources of the data. Section 4 presents and discusses our results, emphasizing magnitudes, signs, and identifiability. Section 5 concludes the paper, discussing limitations and implications.

2 Preceding Effects of the EUDR in the Global South

Even before coming into force, the EUDR brought about changes and rearrangements around the world. This is because the EU, even during debates on the new regulation that would replace the EUTR (European Timber Regulation), was already capable of causing upheaval and even pressure from countries exporting primary commodities. If analyzed from the perspective of the telecoupling framework, it would be called "regulatory spillovers" (Trevizan, 2024a). However, in this work, they are referred to as "side effects" of the EUDR and precedentialial effects. Precedentialial effects are

understood as effects which can be detected even before the law comes into force. This phenomenon occurs due to the de facto Brussels Effect, in which trade and private stakeholders adapt their operations and value chains to the new parameters in advance; and also as a result of the de jure Brussels Effect, characterized by the preventive adjustment of standards by States internalizing future regulatory standards even before entry into force.

To understand this scenario, it is necessary to grasp how commodity-producing countries to which the EUDR is addressed have been dealing with forest issues and their endogenous problems (Trevizan, 2024b, 2025; Trevizan et al., 2025). To this end, the analysis focuses on how these countries reacted to the EUDR and what possible effects may arise from it.

Indonesia is the first country considered here. Interestingly, like Brazil, Indonesia has the particularity of possessing lush tropical forests and also being an exporter of commodities to the EU, such as wood and palm oil, cocoa, coffee, and rubber. Because of the EUDR—and out of fear of being unable to continue trading its commodities with the EU—Indonesia has pursued regulatory and structural compliance to ensure strict traceability by expanding its zero-deforestation criteria for forest products (Fisher, Ekaputri, Obidzinski, & Alves, 2024).

Next, Colombia has made an effort to comply with the EUDR concerning coffee through ongoing projects (*Aseguramiento de la sostenibilidad de la cadena de valor del café Colombiano*, n.d.). It is noted that Colombia has taken an approach more grounded in preexisting agreements and has issued guidelines to facilitate internal compliance (*Launch of the "Guide to Strengthen Due Diligence of Cooperatives in the Coffee Sector" in Colombia*, 2025).

The third country analyzed is Peru. Like other Amazonian countries, Peru is among the largest exporters of tropical timber in South America and participates in the international trade of primary commodities such as coffee and cocoa. What is observed, however, is a contradiction: while the country has sought to meet the traceability requirements imposed by the EUDR, it has also passed legislation allowing the regularization of illegally deforested areas in the past, especially by small family farmers (Giudice & Börner, 2024). This is an attempt to align with the principle of "legal production" required by Article 3 of the European regulation. However, such a measure disregards the environmental safeguards required under the Paris Agreement framework and may, in practice, weaken internationally assumed climate commitments.

Even so, institutional efforts toward digitalization and territorial control must be recognized. The *Servicio Nacional Forestal y de Fauna Silvestre* implemented the "Trazabilidad de los Recursos Forestales Maderables", focused on timber traceability (Servicio Nacional Forestal y de Fauna Silvestre, 2019). Added to this is the construction of a national forest data platform, supported by international initiatives such as REDD+. The Peruvian case, therefore, reveals an ambiguous side effect: there are technical and digital advances consistent with the EUDR, but also internal regulatory setbacks that contradict the *animus legis* of the regulation, which aims to combat climate change. Therefore, this confirms the hypothesis of this study that the preceding effects of the EUDR often do not result in concrete environmental benefits.

Next, the case of Malaysia is analyzed. Malaysia's export profile includes primary commodities such as palm oil and tropical timber, and it has adopted a strategic institutional position to meet European requirements. As early as 2020, the national government made MSPO (Malaysian Sustainable Palm Oil) certification mandatory, covering 100% of national palm oil production, including smallholders (Aziz, Chamhuri, & Batt, 2021; Wan, 2022), thereby ensuring regulatory compliance with the due diligence logic of the EUDR. This process generated internal rearrangements, such as the implementation of digital tracking "from field to port", the development of a new standard for the natural rubber supply chain, and the use of drones and satellites for territorial and forest monitoring in the states of Sarawak and Sabah (European Forest Institute, 2025; Kannan, 2023; Ng, Chervier, Ancrenaz, Naito, & Karsenty, 2022). Although these movements are often presented as sovereign responses to the country's internal needs, the catalytic role of European regulation in shaping these strategies cannot be disregarded. This is, once again, a preceding effect that reaffirms

the transnational strength of the European norm even before it enters into force.

Côte d'Ivoire, in turn, stands out on the African continent, especially as the world's largest cocoa exporter and a country deeply affected by deforestation as a result (Kalischek et al., 2023). In 2022, the country launched the National Sustainable Cocoa Strategy, aiming to make this supply chain sustainable (Dominique, 2025). To that end, Côte d'Ivoire implemented a national digital traceability system requiring identification by lot of origin and individualized digital registration of producers, including photo and ID number. In total, around 900,000 producers have already been integrated into the system (Aboa, 2025). Furthermore, the country received €300 million in budgetary support from the EU to enable the adaptation of its production chains to the new regulatory framework (European Investment Bank, 2025). However, as warned by authors who critically analyze the EUDR (Fisher et al., 2024), such traceability measures may have as a side effect the exclusion of small producers unable to meet the imposed criteria. There is, therefore, a concrete risk that the EUDR will end up consolidating technical and social barriers disguised as environmental measures, which, within this study, are revealed as limitations of the *animus legis* of the European norm in light of the complex realities of the Global South.

Vietnam is the second-largest coffee exporter in the world, particularly due to its wide variety, and it also acts as a global hub in the wooden furniture and rubber product industries. The EU absorbs about 41% of Vietnam's coffee exports (United States Department of Agriculture, 2025), as well as significant volumes of wooden furniture, making the country a central actor in the supply chains regulated by the EUDR (*Country Profile – Viet Nam*, n.d.). Not by chance, Vietnam was one of the first countries to adopt a cooperative institutional stance toward the European regulation.

In 2023, the National Action Plan for Vietnam's Agriculture Sector was launched to adapt to the EUDR (Linh, 2024). In December 2024, the EUDR Database System for Forest and Coffee Growing Areas was formally launched, with support from the IDH Initiative and the Ministry of Agriculture and Rural Development (MARD), aimed at integrating forest maps, geographic coordinates, and land tenure data to trace farms (IDH, 2024).

Vietnam's regulatory response is an example of "strategic compliance" used as an incentive for agricultural modernization and reputational positioning. However, structural challenges persist—most notably, the fact that the majority of small coffee growers, particularly from ethnic minorities, still lack formal land titles, which makes it difficult to prove legality as required by Article 3 of the EUDR. Thus, alternative solutions are being discussed, such as local authority declarations, collective validation, and technical training for producers to maintain records. All these mechanisms, though necessary, may shift the regulatory burden onto actors with limited institutional capacity (Voice Network & Forest Trends, 2025) and create even greater social inequalities in Vietnam.

On the African continent, Ghana's case deserves attention. The country is the world's second-largest cocoa producer, with the EU purchasing about 80% of its exports. In 2023, the EU Sustainable Cocoa Programme established a partnership with Ghana for sustainable cocoa aligned with the EUDR guidelines (Directorate-General for International Partnerships, 2023)—a digital system that tracks cocoa from the farm to the port, with georeferencing and producer ID.

Although no formal legislative changes have occurred, Ghana's cocoa regulatory authority issued binding operational guidelines (GSA, 2023), creating a parallel and functional regulatory architecture for compliance. Traceability was strengthened through digitalization initiatives, voluntary certifications (Rainforest Alliance, Fairtrade), and even the distribution of GPS devices to small producers (GSA, 2023). As pointed out by local NGOs—and applying critical reasoning—it is evident that the true driver of deforestation in the cocoa supply chain is rural poverty, and without fair pricing policies or subsidies, the EUDR risks reproducing the exclusion of the most vulnerable farmers (World Cocoa Foundation, n.d.). Hence, a clear preceding effect emerges, in which environmental regulation has a negative socioeconomic impact, serving as a driver of further inequality (World Cocoa Foundation, 2024).

From this analysis, it is concluded that the preceding effects of the EUDR, although aiming for

normative alignment in pursuit of sustainability, often conceal mechanisms that fail to promote environmental and climate justice. On the contrary, they reinforce the outsourcing of forest governance to countries in the Global South, reshaping their legal, administrative, and productive dynamics without clear responsibility on the part of the EU.

3 Methods

This paper deploys several methods to answer its main questions: Are there, if any, anticipatory effects of the EUDR in Brazil, especially considering deforestation and land use? The answer to this question involves the collection of deforestation, production, and export data for all Brazilian municipalities for several years. Deforestation and production data are readily available through Hansen et al. (2013) and Instituto Brasileiro de Geografia e Estatística's Annual Agricultural Research. However, difficulties arise with export data, which will be explained in the subsection below.

In terms of identification strategy, given the EUDR timeline of creation, enactment, and having its full effects, there should exist some anticipatory effects, given the fact that although the EUDR has its full effects in 2027, it prohibits imports from deforested areas after 2020 for a selection of goods. We deploy an impact analysis that allows us to identify when the EUDR impact probably starts and whether this impact is relevant for the Brazilian context in terms of deforestation and land use.

3.1 Exports Imputation

Although Brazil has official data available for municipal exports, this data, as Leal and Martins (2025) displayed, does not pertain to the production directed to foreign markets, being related to the bureaucracy related to exports. In other words, official Brazilian data on exports locate traders in space, not producers. This is a relevant shortcoming in data, one that Leal and Martins (2025) propose a new method to overcome. This method is explained below. This algorithm considers that true municipal data are spatially related and whenever this relationship does not amount to equality, we employ a correction factor, based on a relevant variable the researcher finds most well suited to explain the exporting variable. In this way, following Leal and Martins (2025) directly, considering k as the number of goods at level Harmonized System 6 (HS6) present under a category of the Harmonized System 4 (HS4), then the exports of municipality i at the HS6 level are given by:

$$E_{i,\text{HS6}} = \alpha \mathbf{W} E_{i,\text{HS4}} + r E^*_{i,\text{HS6}}, \tag{1}$$

where

- i is a municipality.
- $E_{i,\text{HS6}}$ are the estimated municipal exports at the HS6 level.
- $E^*_{i,\text{HS6}}$ is defined as $\sum_{i=1}^{I} \alpha(E_{i,\text{HS4}} - \mathbf{W} E_{i,\text{HS4}})$.
- α is the proportion coefficient at the state level defined as:

$$\alpha = \frac{E_{\text{state,HS6}}}{E_{\text{state,HS4}}}, \tag{2}$$

  where E means exports, therefore $E_{\text{state,HS6}}$ means state exports of a given good at the HS6 level, while $E_{\text{state,HS4}}$ means state exports of the good category at the HS4 level.

- **W** is a row-normalized $n \times n$ spatial weights matrix where n is the number of municipalities, such that:

$$\sum_{j=1}^{n} w_{ij} = 1, \quad \forall i \tag{3}$$

and $w_{ij} \geq 0, \forall i, j$.

- r is an $n \times 1$ vector that sums to 1. In this work, it is considered to be the relevance of each municipality in the state's formal workforce in the soybean sector.

- $E_{i,\text{HS4}}$ is an $n \times 1$ vector of observed municipal exports at the HS4 level, where the superscript * indicates that some entries may be zero.

This algorithm is sum-consistent, allows for zero exports in municipalities, and is dimensionally consistent. **W** can be any spatial weight matrix, where r can be any vector that adds up to 1. In this paper, we employ an inverse-weight matrix and use RAIS to create our relevance vector, following Leal and Martins (2025).

3.2 Impact Analysis: A Continuous-Dose Experiment

We employ a panel regression analysis that leverages several sources of exogeneity. The first one is the possible year of the EUDR effect, which due to data constraints, can be qualified reasonably as 2021, 2022, or 2023. Looking more directly at Brazilian municipalities, we have further exogeneity sources, which are different exposures to the EUDR in terms of goods, that is, they might have an export profile apart from the EUDR, and they might export differently to the EU, that is, some municipalities export overall more to the EU than others. These exogenous variations create a thoroughly ample scenario that allows for qualifying the possible anticipatory effect of the EUDR on deforestation and land use. Our main empirical equation is given by:

$$\begin{aligned} Y_{i,t} = \beta_1 \text{EU}_{i,t} + \beta_2 \text{EUDR_Exp}_{i,t} + \beta_3 \text{EUDR}_{i,t} + \beta_4 \text{EU}_{i,t} \times \text{EUDR_Exp}_{i,t} \\ + \beta_5 \text{EU}_{i,t} \times \text{EUDR}_{i,t} + \beta_6 \text{EUDR}_{i,t} \times \text{EUDR_Exp}_{i,t} \\ + \tau \text{EU}_{i,t} \times \text{EUDR_Exp}_{i,t} \times \text{EUDR}_{i,t} + \alpha_i + \gamma_t, \end{aligned} \tag{4}$$

where $Y_{i,t}$ is deforestation and land use change in municipality i in time t (with the Inverse Hyperbolic Sine Transformation applied, to account for null values). Deforestation is measured as in Hansen2013 and land use is defined as the share of EUDR agricultural goods under all agricultural production, in area. $\text{EU}_{i,t}$ indicates whether the European Union is a relevant destination to the exports of municipality i in time t. This is a continuous variable. $\text{EUDR_Exp}_{i,t}$ is the exposure of the exports of a given municipality i in time t to the EUDR's selection of goods. $\text{EUDR}_{i,t}$ is a time dummy indicating when the EUDR should exert the most impact on the dependent variables (2021, 2022, or 2023).

Our main effect is given by $\text{EU}_{i,t} \times \text{EUDR_Exp}_{i,t} \times \text{EUDR}_{i,t}$ and is captured by the parameter τ. This parameter indicates if the effect of the EUDR is already present on deforestation and land use whenever significant. We expect it to be negative for deforestation and land use (landowners might produce something else than the EUDR's selection of goods).

We implement placebo tests (changing the treatment and testing for pre-treatment effects) in order to certify that our results are causal and not simply artifacts.

4 Results

We present in Table 1 the main results on deforestation considering 2021, 2022, and 2023 as possible years of treatment[1].

Table 1: Effect of EUDR on municipal deforestation (Inverse Hyperbolic Sine Transformation)

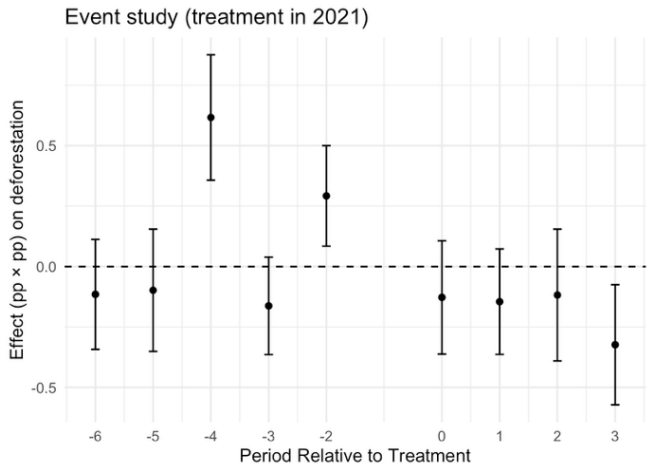
Variable	**2021**	**2022**	**2023**
Exps_Exposure	0.528***	0.568***	0.605***
	(0.080)	(0.078)	(0.074)
Exps_EUDR	−0.050	−0.003	0.023
	(0.047)	(0.045)	(0.045)
EUDR_total_share	0.266***	0.145**	0.098
	(0.064)	(0.066)	(0.073)
EUDR_t × Exps_Exposure	0.083**	−0.070*	−0.161***
	(0.036)	(0.037)	(0.042)
EUDR_t × Exps_EUDR	0.225	−0.001	−0.157
	(0.215)	(0.209)	(0.208)
Exps_Exposure × Exps_EUDR	−0.753***	0.028	0.477**
	(0.189)	(0.192)	(0.229)
EUDR_t × Exps_Exposure × Exps_EUDR	−0.753***	**0.028**	**0.477****
(Triple interaction)	*(0.189)*	*(0.192)*	*(0.229)*
Municipality FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	45,978	45,978	45,978
Municipalities	4,598	4,598	4,598
Years	2015–2024	2015–2024	2015–2024
Adj. R^2	0.9299	0.9299	0.9300
Within R^2	0.0037	0.0038	0.0043
RMSE	0.3391	0.3391	0.3390

Note: Authors' elaboration. Dependent variable: inverse hyperbolic sine transformation of deforestation in km^2 (Hansen et al., 2013). Robust standard errors clustered at municipality level in parentheses. Treatment years represent: 2021 (EUDR proposal), 2022 (ongoing negotiation), 2023 (regulation enactment). The triple interaction coefficient captures the differential effect of EUDR on municipalities with high exposure to both EU markets and EUDR-covered commodities. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

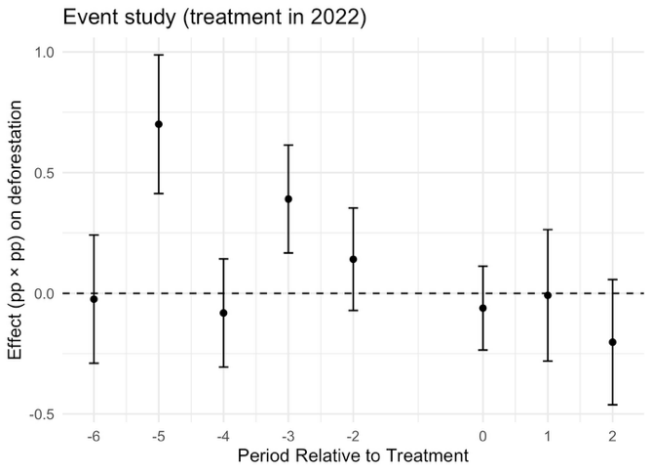
Results indicate different effect patterns across the potential treatment years, though these estimates face identification challenges discussed below. The triple interaction coefficient for 2021 is negative and significant, which—if interpreted causally—would suggest that municipalities with high EUDR exposure reduced deforestation relative to controls, consistent with anticipatory compliance behavior. The coefficient for 2023 reverses sign, becoming positive and significant, which would indicate that these same municipalities subsequently increased deforestation beyond counterfactual levels. The 2022 coefficient is statistically indistinguishable from zero, potentially reflecting a transitional period between the initial compliance response and subsequent behavioral reversal. These effects, however, are not entirely identifiable, given that a Wald test on pre-treatment effects is rejected under 1%. Hence, our parallel trends assumption does not seem to hold. Figure 1 indicates the event study used to calculate these Wald statistics. Evidence for parallel trends would manifest

[1]In the Appendix, we present figures describing the behavior through time of the variables used in this analysis.

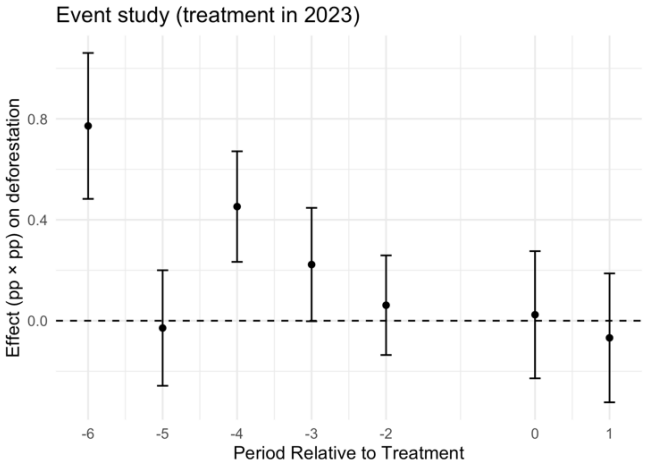
graphically in non-significant effects prior to the treatment year, which is not the case for 2021, 2022, and 2023.



(a) 2021



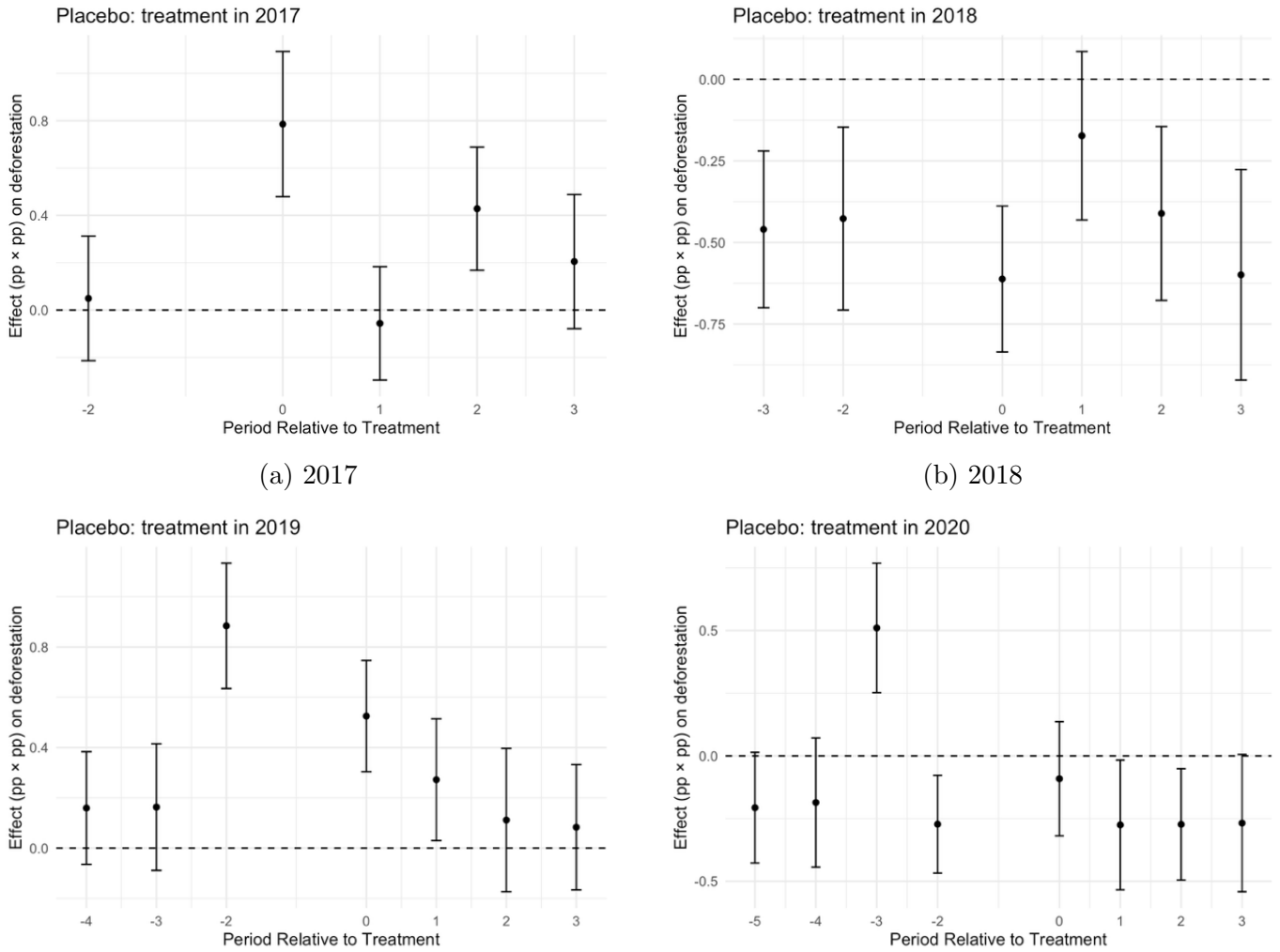
(b) 2022



(c) 2023

Figure 1: Event study for deforestation (2021, 2022, 2023)
Note. Authors' elaboration.

A placebo test of dislocating treatment to 2017, 2018, 2019, and 2020 is also inconclusive as Figure 2 indicates. In this case, one would expect non-significance before and after the hypothetical year, which is not the case for any of the four years considered (2017, 2018, 2019, 2020).



(a) 2017

(b) 2018

(c) 2019

(d) 2020

Figure 2: Event study for deforestation: Placebo (2017, 2018, 2019, 2020)
Note. Authors' elaboration.

Overall, there is a strong argument that our 2021, 2022, and 2023 results are not identifiable effects, although the 2021 and 2023 coefficients are significant. However, if they were properly identified, that would mean that the EUDR does not act as a deterrent to deforestation, at least for Brazilian municipalities.

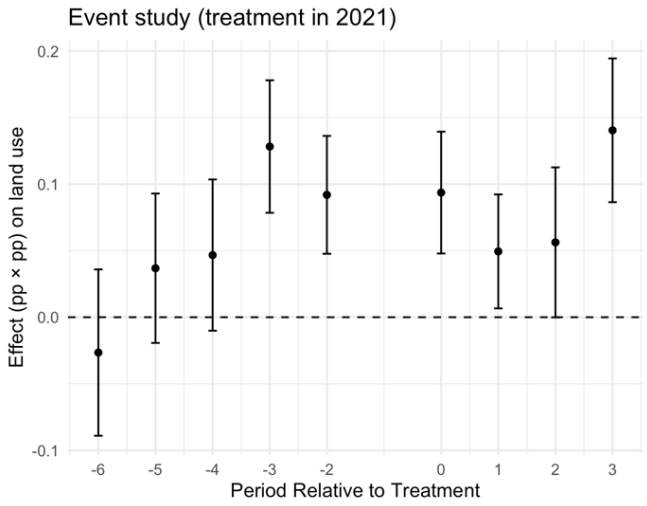
Next, we present the results for land use change within Brazilian municipalities in Table 2.

Table 2: Effect of EUDR on municipal land use (Inverse Hyperbolic Sine Transformation)

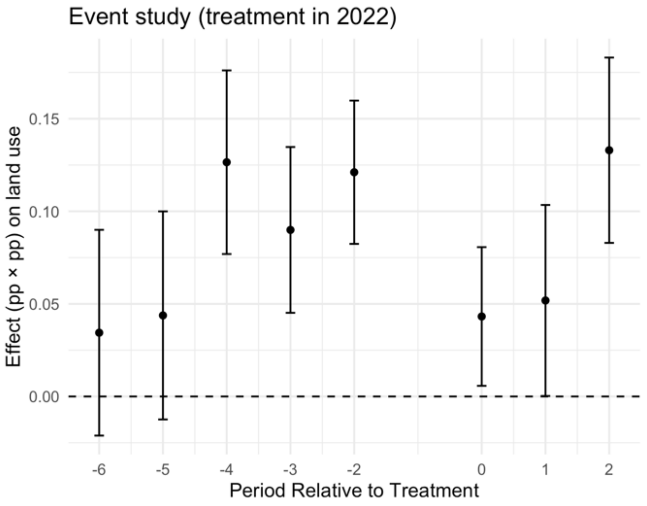
Variable	**2021**	**2022**	**2023**
Exps_Exposure	−0.040**	−0.045***	−0.065***
	(0.017)	(0.016)	(0.016)
Exps_EUDR	0.065***	0.062***	0.055***
	(0.014)	(0.014)	(0.014)
EUDR_t × Exps_Exposure	−0.147***	−0.159***	−0.155***
	(0.015)	(0.016)	(0.015)
EUDR_t × Exps_EUDR	−0.033***	−0.031***	−0.019**
	(0.008)	(0.008)	(0.009)
Exps_Exposure × Exps_EUDR	−0.103*	−0.085	−0.046
	(0.057)	(0.056)	(0.055)
EUDR_t × Exps_Exposure × Exps_EUDR	**0.225*** **	**0.212*** **	**0.172*** **
(Triple interaction)	*(0.041)*	*(0.043)*	*(0.047)*
Municipality FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	45,721	45,721	45,721
Municipalities	4,577	4,577	4,577
Years	2015–2024	2015–2024	2015–2024
Adj. R^2	0.9506	0.9506	0.9506
Within R^2	0.0093	0.0094	0.0091
RMSE	0.0599	0.0599	0.0599

Note: Authors' elaboration. Dependent variable: inverse hyperbolic sine transformation of land use share devoted to EUDR-covered commodities (soy, coffee, beef, cocoa, palm oil, rubber, wood) in total agricultural land. Robust standard errors clustered at municipality level in parentheses. The triple interaction coefficient captures the differential effect of EUDR on land allocation decisions in municipalities with high exposure to both EU markets and EUDR-covered commodities. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

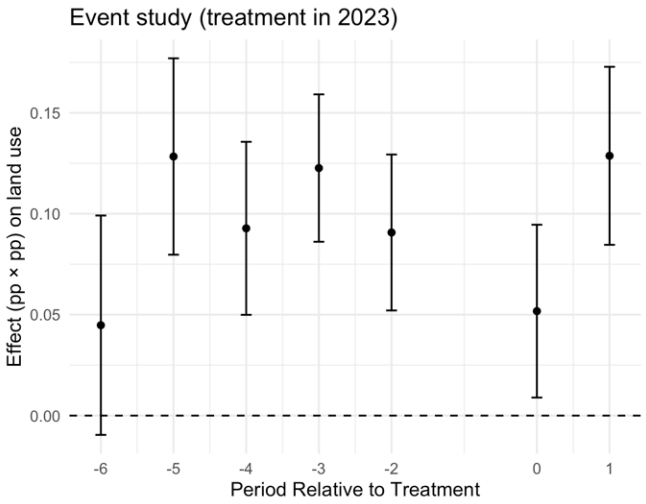
Results indicate that EUDR effects would increase the weight of EUDR products in the export share of Brazilian municipalities. This effect, similar to the deforestation effect, does not seem particularly well identified, given that under 1% pre-treatment effects are not statistically null; hence the parallel trend hypothesis does not hold. Figure 3 displays the event study for all possible treatment years (2021, 2022, 2023), from which we calculated the Wald statistics.



(a) 2021



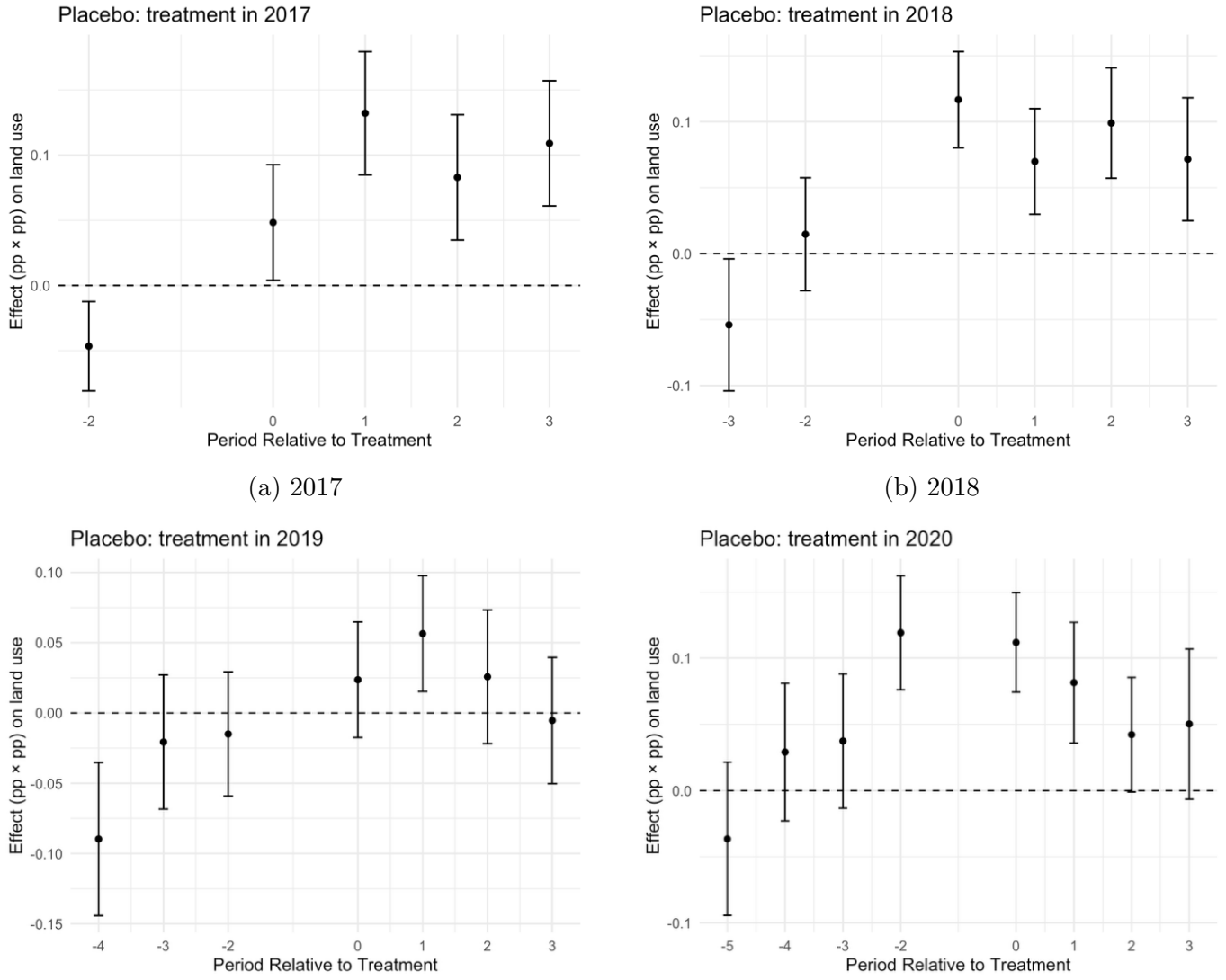
(b) 2022



(c) 2023

Figure 3: Event study for land use (2021, 2022, 2023)
Note. Authors' elaboration.

Figure 3 indicates that there is a significant effect prior to our treatment, which means that our treatment effect is not correctly identified. Figure 4 uses different treatment years (2017, 2018, 2019, 2020) as a placebo test.



(a) 2017

(b) 2018

(c) 2019

(d) 2020

Figure 4: Event study for land use: Placebo (2017, 2018, 2019, 2020)
Note. Authors' elaboration.

The significant effects indicate that this model for land use is not well identified either. However, if these models were well identified, they would mean that municipalities more exposed to the EUDR would specialize even further in producing the EUDR products. In a sense, given the sunk cost of complying with the EUDR, there would exist an incentive to produce even more of the EUDR goods and direct their exports toward the European Union.

Although our main effect is not properly characterized, beyond magnitudes and signs, it is relevant to mention the underlying hypothesis underlying this work, which is that EUDR effects were already anticipated by several agents. That does not seem to be the case, and these paragraphs aim to argue for this interpretation. If the EUDR were to have any anticipatory effect, our three possible treatment models (2021, 2022, 2023) would have produced an identified effect. By identified effect, we mean not only significant and reasonable coefficients, but the upholding of two constraints: (i) parallel trends assumption; (ii) placebo tests (2017, 2018, 2019, 2020) not informative and consistent with null effects before and after this hypothesized effect. These two constraints are violated; hence our effect is not identifiable. Although not identifiable, these results do not ascertain that the EUDR has no anticipatory effects; they only ascertain that for the timeline considered (2015–2024), the EUDR was not strong enough to motivate any change. Considering future data and when the EUDR has its full effect, a researcher might be able to capture the EUDR's anticipatory effect. In a sense,

this paper aimed to launch the kind of debate relevant to whether the European Union is able to affect other countries' economic decisions. This does not seem to be the case here.

However not identifiable, these results are informative in the sense of indicating possible dynamics at play. In that way, the deforestation and land use results indicate that in 2021 there is an intensification of EUDR crops without any further deforestation, that is, there is an intensification in production, not an expansion. Results for 2022 indicate that intensification persists, although there is no significant change in deforestation. For 2023, however, an intensification paired with an expansion happens simultaneously, indicating larger deforestation and EUDR product specialization.

We then conclude that so far the EUDR does not seem to have had any effect on Brazilian deforestation and land use, considering these anticipatory lenses. This does not mean that the regulation is ineffective or will be ineffective. These anticipatory effects analyses rest on the hypothesis that agents will act to comply with a certain regulation before it has its full effects. That might be reasonable to expect from some producers in terms of goods and regions producing them. This result might also not generalize in the same way for other countries with other economic and environmental realities, in terms of deforestation, EU relevance as a destination of exports, and EUDR goods as a relevant part of the exports.

5 Concluding Remarks

This paper aimed to characterize an important question regarding trade, environment, and geopolitics: Does the new European Union Regulation on Deforestation-Free Products already have any impact on deforestation and land use patterns in Brazilian municipalities? We found positive impacts, although these effects do not appear properly identified. Beyond the econometric analysis, this paper innovates in other directions: an extensive legal analysis examining how EUDR regulation is driving change in Global South countries even before the regulation takes effect in 2027, finding that regulatory frameworks are already being established to comply with EUDR.

The legal analysis indicates this compliance movement; however, it asserts the division of responsibilities is highly unequal among countries and depends on how they engage in trade relationships with the EU. It is important to mention that countries have different options available in how they respond to EUDR. Countries with more trade partners will probably fare better and can choose not to comply entirely with EUDR. Although the Brussels effect is a legal and regulatory concept, its strength is based on the strength of the economic relationship between the EU and a third country. Although there might be some second- and third-order diffusion mechanisms, it is relevant to mention that EUDR will affect countries in different magnitudes. However, if some regulation similar to EUDR becomes the standard, then the Brussels effect is happening in a web-like fashion, not necessarily on a single-country basis. The extraterritorial diffusion of EUDR might also cause an inability to legislate by third countries, where complying with EUDR reduces the legal freedom they have to find regulation and laws that fit within their regulatory framework and social-political desires. In other words, this ambitious fit-for-purpose EU regulation might hinder the forest conservation efforts of many countries just to green the EU deforestation fingerprint. Hence, although EUDR might be effective to European Union do induce less deforestation, it can, via general equilibrium effects, induce higher deforestation levels elsewhere.

Bringing together the legal and econometric analysis, an argument can be made that EUDR might have some partial compliance happening in Brazil; however, this compliance is neither full nor uniform across deforestation and land use patterns or across Brazilian municipalities. Although the non-identification limits the conclusions drawn from EUDR's anticipatory effects on Brazilian municipalities, our legal analysis points to a direction in which partial compliance with EUDR is happening; however, this compliance is not strong enough to drive change in deforestation and land use patterns. Future work will have more timely data, although the methods used here seem well positioned to help different researchers gauge the impact of EUDR once this regulation takes full

effect.

References

Aboa, A. (2025, July 24). *Small ivory coast cocoa firms say eu deforestation rules might bankrupt them.* Retrieved from https://www.reuters.com/sustainability/climate-energy/small-ivory-coast-cocoa-firms-say-eu-deforestation-rules-might-bankrupt-them-2025-07-24/

Aseguramiento de la sostenibilidad de la cadena de valor del café colombiano. (n.d.). Retrieved from https://alinvest-verde.eu/en_gb/aseguramiento-de-la-sostenibilidad-de-la-cadena-de-valor-del-cafe-colombiano/ (Retrieved October 27, 2025)

Aziz, N. F., Chamhuri, N., & Batt, P. J. (2021). Barriers and benefits arising from the adoption of sustainable certification for smallholder oil palm producers in malaysia: A systematic review of literature. *Sustainability*, *13*(18), 10009. doi: 10.3390/su131810009

Bradford, A. (2020). *The brussels effect: How the european union rules the world*. Oxford University Press.

Brandão, A., Jr., Souza, C., Jr., Ribeiro, J., & Sales, M. (2025). Deforestation and cattle ranching drive forest degradation in the amazon. *Environmental Research Letters*, *20*(1).

Country profile – viet nam. (n.d.). Retrieved from https://flegtimm.eu/country-profiles/viet-nam/ (Retrieved October 29, 2025)

Dechezleprêtre, A., & Sato, M. (2017). The impacts of environmental regulations on competitiveness. *Review of Environmental Economics and Policy*, *11*(2), 183–206. doi: 10.1093/reep/rex013

Directorate-General for International Partnerships. (2023, May 30). *Unpacking the eu deforestation regulation for the cocoa sector.* Retrieved from https://international-partnerships.ec.europa.eu/publications-library/unpacking-eu-deforestation-regulation-cocoa-sector_en

Dominique, K. (2025, April 15). *The sustainable cocoa programme: Improving the livelihoods of millions of cocoa farmers in côte d'ivoire.* Retrieved from https://www.fao.org/investment-centre/latest/news/detail/the-sustainable-cocoa-programme--improving-the-livelihoods-of-millions-of-cocoa-farmers-in-c%C3%B4te-d%27ivoire/en

European Forest Institute. (2025). *Policy brief options to broaden smallholder inclusivity in legal and deforestation-free palm oil supply chains in malaysia purpose* (Tech. Rep.). doi: 10.22004/ag.econ.124277

European Investment Bank. (2025). *Côte d'ivoire: Global gateway - team europe steps up support for strategic and sustainable investment by €300 million.* Retrieved from https://www.eib.org/en/press/all/2025-012-global-gateway-l-equipe-europe-renforce-a-hauteur-de-300-millions-d-euros-son-soutien-a-des-investissements-strategiques-et-durables-en-cote-d-ivoire

Fisher, M. R., Ekaputri, A. D., Obidzinski, K., & Alves, A. M. (2024). *Commodities and global climate governance: Early evidence from the eu deforestation-free regulation (eudr)* (Tech. Rep.). East-West Center. Retrieved from https://hdl.handle.net/10125/110279

Giudice, R., & Börner, J. (2024). Cost-effectiveness and income effects of alternative forest conservation policy mixes for the peruvian amazon. *Land Use Policy*, *143*, 107197. doi: 10.1016/j.landusepol.2024.107197

GSA. (2023). *Ghana standard gs ig 2: 2023 national implementation guide for gs ars 1000-part 2: Requirements for cocoa quality and traceability* (Tech. Rep.). Retrieved from https://cocobod.gh/resource_files/national-implementation-guide-for-gs-ars-1000-part-2.pdf

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., ... Townshend, J. R. G. (2013). High-resolution global maps of 21st-century forest cover change. *Science*, *342*(6160), 850–853. doi: 10.1126/science.1244693

Heilmayr, R., Rausch, L. L., Munger, J., & Gibbs, H. K. (2020). Brazil's amazon soy moratorium reduced deforestation. *Nature Food*, *1*, 801–810. doi: 10.1038/s43016-020-00194-5

IDH. (2024, December 17). *Vietnam's eudr database system for forest and coffee growing.* Retrieved from https://idh.org/news/vietnams-coffee-sector-marks-a-landmark-step-towards-sustainability-launching-the-eudr-database-system-for-forest-and-coffee-growing-areas

IPCC. (2021). *Climate change 2021: The physical science basis. contribution of working group i to the sixth assessment report of the intergovernmental panel on climate change* (Tech. Rep.). Cambridge University Press.

Kalischek, N., Lang, N., Renier, C., Daudt, R. C., Addoah, T., Thompson, W., ... Wegner, J. D. (2023). Cocoa plantations are associated with deforestation in côte d'ivoire and ghana. *Nature Food*, *4*(5), 384–393. doi: 10.1038/s43016-023-00751-8

Kannan, P. (2023). Digital monitoring and reporting system of oil palm fresh fruit bunch (ffb) transactions: a case study among sustainable oil palm grower cooperative in peninsular malaysia. *Oil Palm Industry Economic Journal*. doi: 10.21894/opiej.2023.05

Launch of the "guide to strengthen due diligence of cooperatives in the coffee sector" in colombia. (2025, September). Retrieved from https://sourceup.org/news-and-updates/launch-of-the-guide-to-strengthen-due-diligence-for-cooperatives-in-the-coffee-sector-in-colombia

Leal, A., & Martins, M. M. V. (2025). Brazilian exports imputation: A new algorithm for estimating the municipal production directed at the foreign market. *Revista Brasileira de Estudos Regionais e Urbanos*, *19*(2), 266–288.

Linh, P. (2024, December 18). *Successfully piloting database system for coffee growing areas.* Retrieved from https://van.nongnghiepmoitruong.vn/successfully-piloting-the-database-system-for-forest-and-coffee-growing-areas-d413853.html

Llopis, J. C., Haddaway, N. R., Omirbek, N., Simmons, B. A., Garrett, R., & Jones, J. P. G. (2023). Evidence of anticipatory forest use behaviours under policy introduction: a systematic map protocol. *Environmental Evidence*, *12*, 20. doi: 10.1186/s13750-023-00307-0

Miranda, J. J., et al. (2019). Land speculation and conservation policy leakage. *Journal of the Association of Environmental and Resource Economists*, *6*(1), 195–237.

Ng, J. S. C., Chervier, C., Ancrenaz, M., Naito, D., & Karsenty, A. (2022). Recent forest and land-use policy changes in sabah, malaysian borneo: Are they truly transformational? *Land Use Policy*, *121*, 106308. doi: 10.1016/j.landusepol.2022.106308

Regulation (EU) 2023/1115 of the European Parliament and of the Council of 31 May 2023 on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation. (2023). *Official Journal of the European Union*, *L 150/206*.

Rittenhouse, K., & Zaragoza-Watkins, M. (2018). Anticipation and environmental regulation. *Journal of Environmental Economics and Management*, *89*, 255–277. doi: 10.1016/j.jeem.2018.03.007

Servicio Nacional Forestal y de Fauna Silvestre. (2019). *Trazabilidad de los recursos forestales maderables* (Tech. Rep.). Repositorio Institucional del SERFOR. Retrieved from http://repositorio.serfor.gob.pe/handle/SERFOR/774

Smulders, S., Tsur, Y., & Zemel, A. (2012). Announcing climate policy: Can a green paradox arise without scarcity? *Journal of Environmental Economics and Management*, *64*(3), 364–376. doi: 10.1016/j.jeem.2012.02.007

Trase. (2025). *Eu deforestation regulation explained.* Retrieved from https://trase.earth/insights/eu-deforestation-regulation-explained

Trevizan, A. F. (2024a). *A influência da união europeia na sustentabilidade global: Enfoque jurídico do efeito bruxelas no comércio de produtos florestais em mato grosso* (Doctoral dissertation,

Universidade Nova de Lisboa). Retrieved from http://hdl.handle.net/10362/177875

Trevizan, A. F. (2024b). Exploring the brussels effect. *Revista de Direito*, *16*(01), 01–25. doi: 10.32361/2024160116014

Trevizan, A. F. (2025). The european union's forest diplomacy: A path toward ostensible environmental sustainability. *Pensar - Revista de Ciências Jurídicas*, *30*, 1–7. doi: 10.5020/2317-2150.2025.16353

Trevizan, A. F., Leal, A. M. M., & Valle, V. E. N. (2025). Forest trade on the amazon frontier and its interaction with the eudr. *International Journal for the Semiotics of Law - Revue Internationale de Sémiotique Juridique*, *38*(5), 1639–1662. doi: 10.1007/s11196-025-10250-7

United States Department of Agriculture. (2025). *Coffee annual* (Tech. Rep.).

Voice Network, & Forest Trends. (2025). *Vietnam coffee sector assessment.*

Wan, A. J. (2022, July 7). *Next generations of smallholders in malaysia.* Retrieved from https://mspo.org.my/next-generations-of-smallholders-in-malaysia/

World Cocoa Foundation. (n.d.). *Cocoa household income study methodology.* Retrieved from https://worldcocoafoundation.org/programmes-and-initiatives/cocoa-household-income-study-methodology (Retrieved October 29, 2025)

World Cocoa Foundation. (2024). *Annual report 2024* (Tech. Rep.).

Appendix

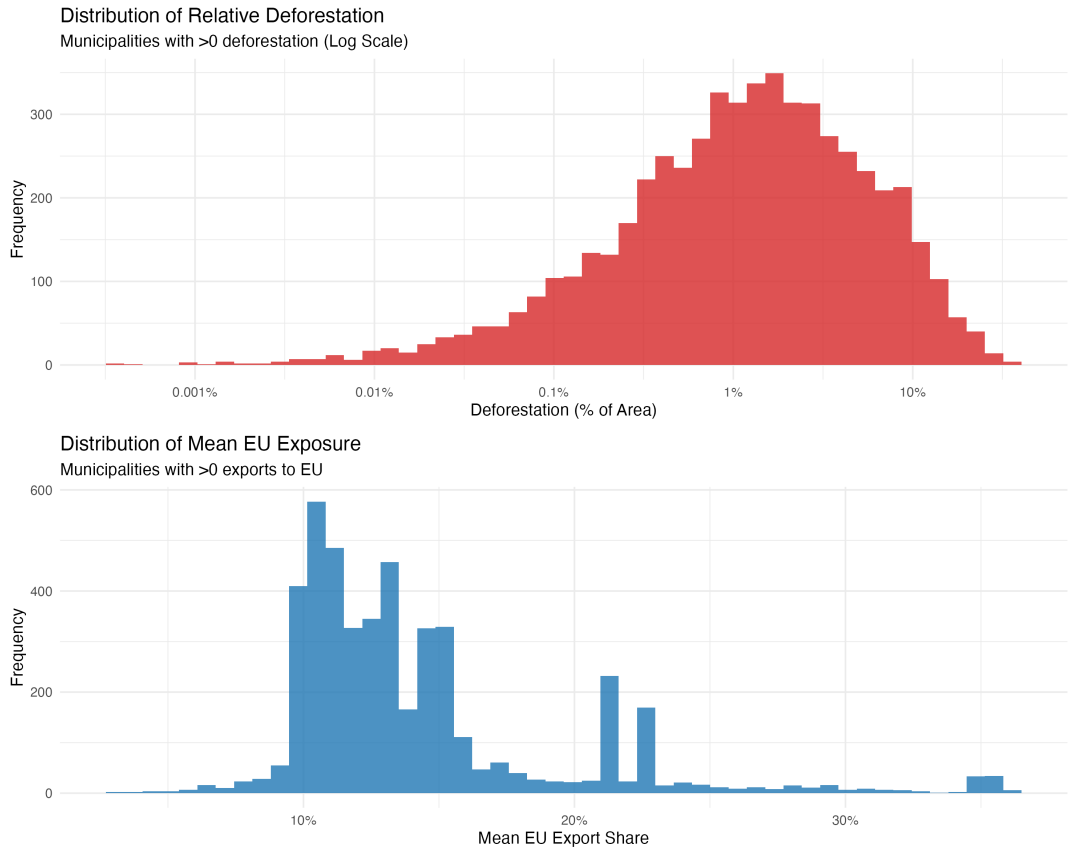


Figure 5: Municipal deforestation and EU exposure (averages over 2015–2024)
Note. Authors' elaboration.

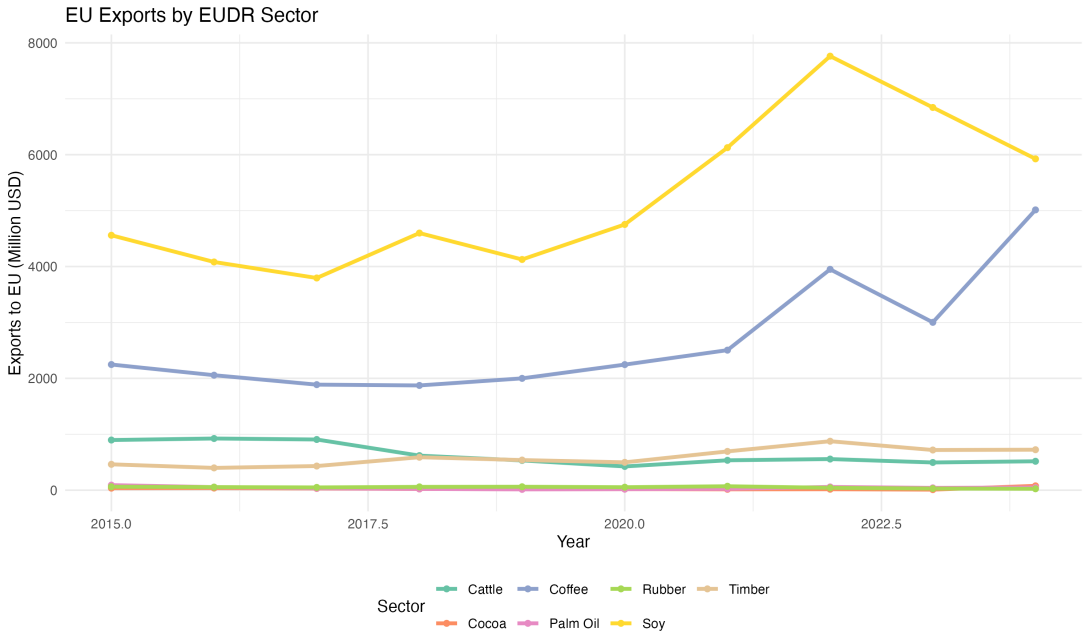


Figure 6: Brazilian exports evolution for the EUDR products
Note. Authors' elaboration.

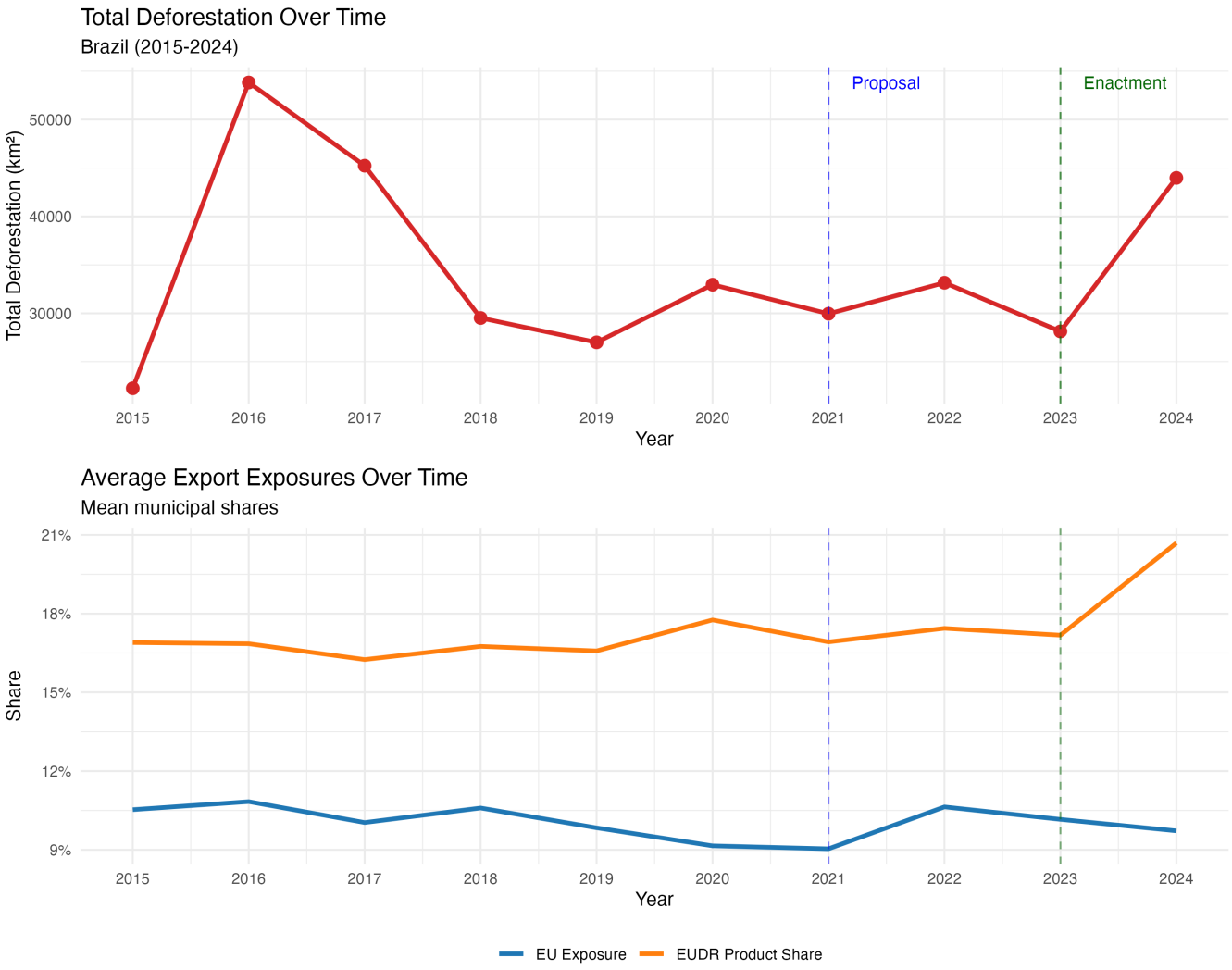


Figure 7: Brazilian trends in deforestation, export relevance of EU, and EUDR products relevance
Note. Authors' elaboration.