Trade and Deforestation: Evidence from Peru

Danielken Molina
Microsoft Corporation

Franco Riottini Depetris
Inter-American Development Bank and UdeSA

Christian Volpe Martincus
Inter-American Development Bank and CESifo

This version: December 2024
Preliminary draft. Please do not circulate.

Abstract

This study investigates the causal relationship between exports and deforestation in Peru, utilizing a shift-share instrumental variables approach to address potential endogeneity. By leveraging district-level variations in export exposure and global demand shocks, the analysis reveals that export activity significantly influences deforestation rates and forest cover. The findings highlight heterogeneity across Peru's regions, with the Amazonian Selva experiencing pronounced deforestation linked to agricultural expansion and resource extraction driven by trade. While exports contribute to economic growth, they exacerbate environmental degradation, particularly in districts lacking governance frameworks or conservation mechanisms. Sectoral analysis demonstrates that agricultural and mining exports are major drivers of forest loss, whereas manufacturing and other goods have more nuanced impacts. The study underscores the importance of integrating environmental considerations into trade policies, suggesting that conservation initiatives and sustainable practices are essential to mitigate the environmental costs of global trade. These insights are critical for policymakers balancing economic development with environmental sustainability, especially in trade-dependent economies with vulnerable ecosystems.

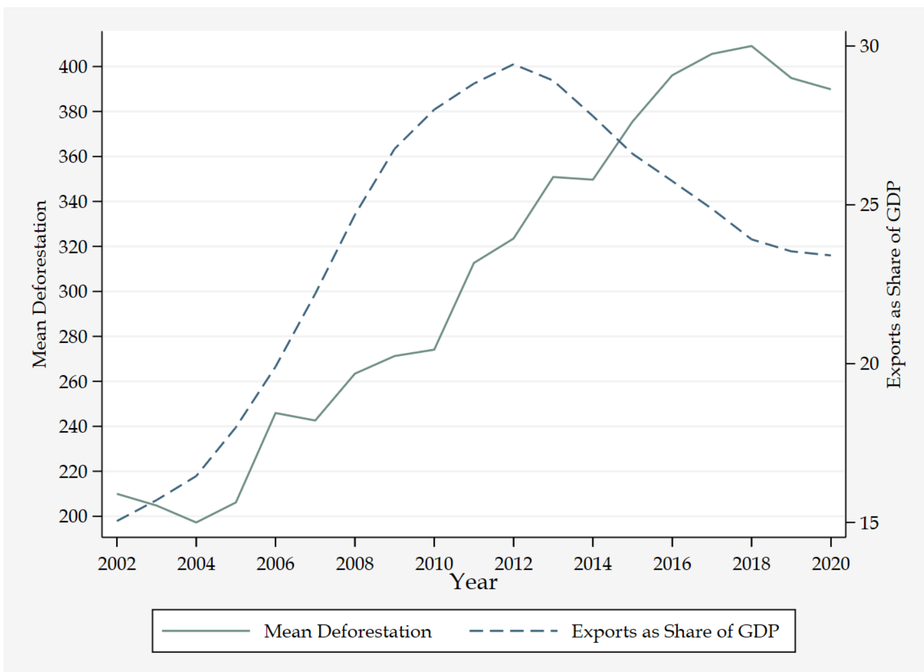
JEL Codes: Q23, Q56, F18, O13, R11

Keywords: Deforestation, International Trade, Environmental Degradation, Shift-Share Instrumental Variables, Sustainable Development, Agricultural Expansion, Peru, Regional Heterogeneity, Natural Resource Management, Trade-Induced Environmental Impact

1. Introduction

Deforestation represents a critical mechanism through which economic activity unfolds, particularly in regions rich in natural resources. This process often results in significant externalities, such as the loss of biodiversity, changes in ecosystem services, and global environmental impacts. While multiple factors drive forest loss, international trade has emerged as a significant force shaping deforestation patterns across developing nations. The linkage between exports and deforestation highlights a fundamental market failure: firms participating in international trade face private costs that differ from the true social costs of their activities. As countries engage in global trade, the demand for natural resources and agricultural products often drives land-use changes at the expense of forests. This dynamic underscores the need to understand deforestation not merely as a local environmental issue but as an integral aspect of the global economic system, where the divergence between private and social marginal costs leads to excessive environmental degradation.

Figure 1: Deforestation and Exports Over Time



The complexity of this relationship is further illustrated in Figure 1, which shows the temporal evolution of average deforestation and exports as a share of GDP in Peru. The time series reveals a striking pattern: both variables show an upward trend over the 2002-2015 period, with exports as share of GDP increasing from around 15% to 30%, while mean deforestation rises from approximately 200 to 400 hectares per district. However, this aggregate correlation over time could be driven by common trends in both variables rather than a causal relationship. For instance, both series might be responding to other factors such as changes in environmental regulations, technological advances, or broader economic development patterns. This temporal correlation, combined with the spatial heterogeneity shown in Figures 1 and 2, underscores the need for a rigorous identification strategy that can isolate the causal effect of trade on deforestation.

The mechanism linking exports to deforestation operates through multiple channels: direct forest clearing for agricultural expansion, infrastructure development for resource extraction, the displacement of local farming into forested areas and manufacturing or industrial activities. Meanwhile, the relationship between exports and deforestation is not obvious from an empirical perspective. Figures 2 and 3 present this relationship at the district level in Peru, revealing substantial heterogeneity in deforestation patterns across regions with similar export levels. While some districts with high export activity show minimal forest loss, others exhibit significant deforestation despite moderate export levels. This empirical pattern suggests two fundamental challenges in analyzing the environmental impact of international trade. First, the relationship between exports and deforestation might be non-linear and heterogeneous across regions. Second, establishing causality is complex: districts with different deforestation levels might naturally attract different levels of export activity, and both variables could be simultaneously determined by unobserved local characteristics.[1]

Figure 2: District Deforestation and Exports (2002 - 2017)

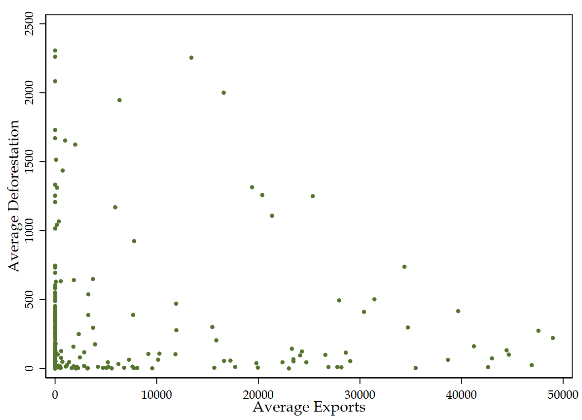
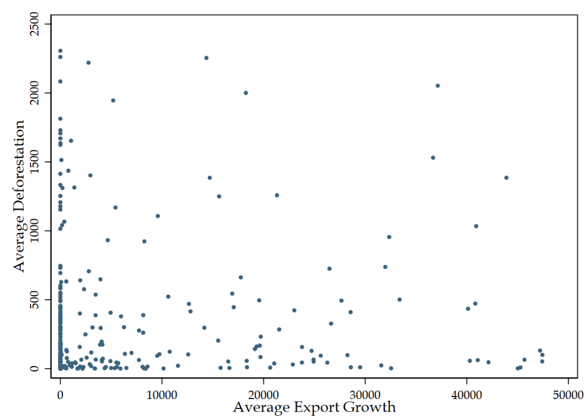


Figure 3: District Deforestation and Exports Growth (2002 - 2017)



To address these empirical challenges, this paper examines the relationship between exports and deforestation in Peru using a shift-share instrumental variables approach. This research design combines the initial economic structure of districts, measured by their participation in GDP during 1995-1998, with global demand shocks for exports to explore patterns of local export exposure. By focusing on district-level variations and incorporating a variety of economic sectors, we analyze how trade patterns relate to deforestation trends over time. This analysis is particularly relevant in the context of Peru, a country that combines rich forest ecosystems with significant export activity, making it an informative setting to study the environmental implications of international trade.

The methodological approach allows us to explore the complex relationships between trade and environmental outcomes, while accounting for various confounding factors. In doing so, we contribute to a nuanced understanding of how economic growth and environmental stewardship interact in an increasingly interconnected world, while also providing insights for policy design in developing nations facing similar trade-offs.

[1]This strikings patterns can also be seen in the Appendix Figure A1. The fact about how is this land being used is also unveiled in Appendix Figure A2, a fact that we will explore causally in the following sections.

2. Literature Review

Deforestation and forest degradation have been the focus of extensive research due to their significant threat to global biodiversity, carbon cycles, and climate stability (Balboni et al., 2023; Dasgupta, 2021). Systematic reviews, such as Borda-Niño et al. (2020), identify key drivers of deforestation, including biophysical factors such as proximity to forest remnants, slope, and soil suitability, alongside socioeconomic variables like accessibility, land tenure, and migration. These findings highlight that deforestation is often concentrated in areas with high agricultural potential and weak governance, while forest conservation thrives in regions with protected areas, steep terrain, and low soil fertility. This underscores the complex interplay of local and global forces shaping land use change and the need for context-specific strategies to mitigate forest loss.

International trade adds another layer of complexity to these dynamics. The exponential growth of trade has heightened demand for agricultural products and natural resources from tropical regions, raising questions about its environmental impacts. Competing hypotheses such as the "race-to-the-bottom," where countries weaken environmental regulations to maintain competitiveness, and the "pollution haven," where trade shifts pollution to low-income countries, frame the debate (Antweiler et al., 2001; Frankel and Rose, 2005). Additionally, the "factor endowment hypothesis" posits that capital-abundant nations export pollution-intensive goods, exacerbating environmental degradation (Copeland and Taylor, 2003). These frameworks highlight how trade affects deforestation through scale, composition, and technique effects (Antweiler et al., 2001). For instance, rising demand for agricultural exports can expand the agricultural frontier (scale effect), while improved market access can promote income growth and, potentially, the adoption of sustainable technologies (technique effect) (Autor et al., 2015; Carreira et al., 2024).

The interaction between trade, deforestation, and health outcomes has gained increasing attention. Du, Li, and Zou (2024) provide evidence from Brazil, showing that trade-induced deforestation not only leads to biodiversity loss but also exacerbates air pollution through slash-and-burn agricultural practices. This pollution affects distant urban areas, increasing respiratory and cardiovascular illnesses. Their findings illustrate the telecoupled nature of trade's environmental costs, linking localized deforestation to widespread health impacts. Moreover, forests' removal disrupts their role as natural carbon sinks, destabilizing global precipitation patterns and accelerating climate change (Balboni et al., 2023; Franklin and Pindyck, 2018).

The cascading effects of deforestation go beyond environmental degradation. As Gong et al. (2023) emphasize, trade shocks can alter air quality, indirectly increasing mortality rates. While previous studies have focused on trade's income and pollution channels (Pierce and Schott, 2020; Bombardini and Li, 2020), natural resource depletion remains an underexplored yet critical pathway. The loss of forest ecosystems diminishes their capacity to filter air pollutants, increasing health risks in downstream populations. These findings highlight the necessity of integrating environmental health considerations into trade policies to ensure the social value of global trade is not undermined.

3. Data

This paper utilizes data from various sources. First, the source of deforestation data is MapBiomas, which provide comprehensive information on forest cover changes in Peru. These datasets allow for a detailed examination of deforestation patterns at the district level, capturing the spatial and temporal dynamics of forest loss[2]. Second, the primary source of data on Peruvian exports at the district level, disaggregated by product (HS6) and destination, is obtained from the Superintendencia Nacional de Aduanas y de Administración Tributaria (SUNAT). For global trade, we rely on the BACI database, which provides worldwide export data.[3] In addition to export data, district-level information is sourced from the Registro Nacional de Municipalidades (RENAMU) and the Instituto Nacional de Estadística e Informática (INEI). This data includes socioeconomic variables such as population and other district-level characteristics, as the area and employment, which are used to control for confounding factors in the econometric model. Finally, district-level GDP is sourced from Seminario and Palomino (2022), who estimate subnational GDP across Peruvian departments and districts using satellite luminosity data.[4]

For product classification, we categorized exports into four main groups—agriculture, mining, manufacturing, and others—using the Standard International Trade Classification (SITC) provided by the United Nations Statistics Division. This classification facilitates a sectoral analysis to explore how the impact of exports on deforestation may vary across different types of economic activity. The data from SUNAT is structured by district, product, and destination, enabling the study to capture each district's exposure to global demand shocks. Specifically, we assigned the SITC sections as follows:

- **Agriculture**: Section 0 (Food and Live Animals)
- **Mining**: Sections 2 (Crude Materials, Inedible, Except Fuels) and 3 (Mineral Fuels, Lubricants, and Related Materials)
- **Manufacturing**: Sections 1 (Beverages and Tobacco), 4 (Animal and Vegetable Oils, Fats, and Waxes), 5 (Chemicals and Related Products, Not Elsewhere Specified), 6 (Manufactured Goods Classified Chiefly by Material), and 7 (Machinery and Transport Equipment)
- **Others**: Sections 8 (Miscellaneous Manufactured Articles) and 9 (Commodities and Transactions Not Classified Elsewhere in the SITC)

This categorization allows for a more precise analysis of the relationship between exports and deforestation across different economic sectors.

[2] Alternatively, we use data from the Ministry of Environment (MINAM) to do some robustness check. MINAM has detailed deforestation data for a sample of districts in Perú.

[3] As will also be explained later, when constructing the instrumental variables, export data from Peru and Latin America and the Caribbean (LAC) are excluded, ensuring the external demand for goods is independent of any endogenous factors linked to Peru's own exports.

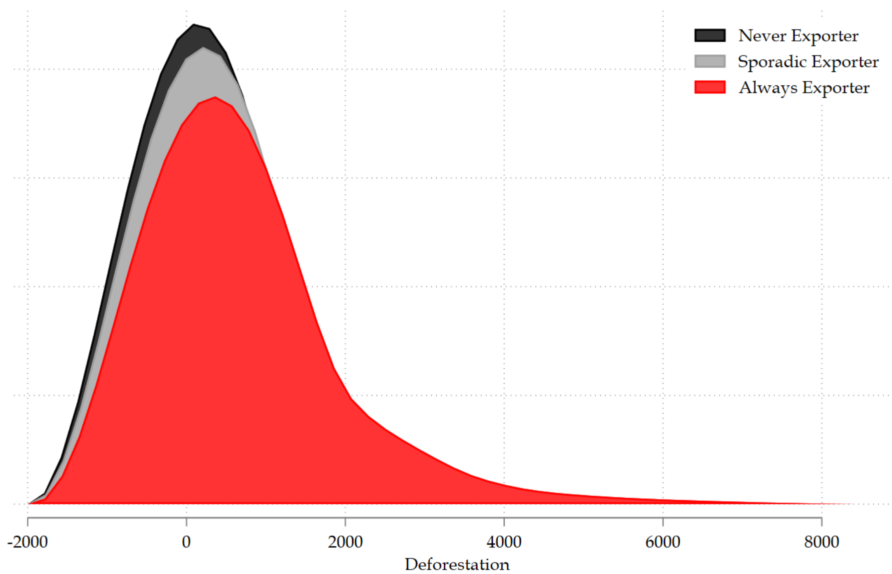
[4] Seminario, B., & Palomino, L. (2022). *Estimación del PIB a nivel subnacional utilizando datos satelitales de luminosidad en el Perú (1993-2018): Base de Datos Regional de Perú 2022* (Actualización a abril de 2022).

4. Descriptive Statistics

4.1 Relationship Between District Export Condition and Deforestation

This subsection starts exploring the relationship between export behavior and deforestation. Figure 4 presents a kernel density plot illustrating the distribution of deforestation across districts grouped into three categories based on their export condition: "Never Exporter," "Sporadic Exporter," and "Always Exporter." The results reveal a positive relationship between export intensity and deforestation levels.

Figure 4: Relationship Between District Export Condition and Deforestation



Districts classified as "Always Exporter" exhibit the widest and highest density distribution at elevated deforestation levels, suggesting a significant environmental impact associated with sustained export activity. In contrast, "Sporadic Exporters" show a more moderate distribution, with lower peaks and reduced dispersion toward extreme deforestation values. Lastly, districts in the "Never Exporter" category concentrate their density near zero, indicating minimal environmental impact.[5]

4.2 Relationship Between Export Growth and Deforestation

Peru is characterized by its extraordinary geographic and ecological diversity, encompassing three major natural regions: the coast, the highlands and the jungle. Each of these areas presents unique biomes, from the arid deserts and fertile coastal valleys, to the high altitude Andes and the vast Amazon basin. This regional heterogeneity is key to understanding how trade and land use dynamics vary at the subnational level, particularly in terms of the

[5] This descriptive analysis aligns with the evidence in Appendix Figure A3, which also highlights marked disparities in deforestation levels across exporter categories.

relationships between export growth and pressures on natural resources. The initial descriptive analysis of this study seeks to illustrate how exports and deforestation have evolved over time and space, and how these trends vary significantly across regions and economic sectors.

Figure 5 illustrates a spatial index, called Export Pressure Index (EPI), measuring the relationship between deforestation and export growth across Peruvian districts. This index is defined as the quotient between the cumulative deforestation of a district and the growth rate of its exports, using the three-year averages of 1999-2001 and 2015-2017 as a reference. Mathematically, the index is calculated as follows:

$$EPI_j = \frac{Deforestation_j}{\Delta Exports_j}$$

Where $Deforestation_j$ is the accumulated deforestation in district j during the period of analysis and

$$\Delta Exports_j = \frac{(\sum_{t=2015}^{2017} Exports_{j,t}/3) - (\sum_{t=1999}^{2001} Exports_{j,t}/3)}{(\sum_{t=1999}^{2001} Exports_{j,t}/3)}$$

Subsequently, the index was normalized on a scale of 0 to 100 to facilitate comparison between districts, using:

$$\overline{EPI_j} = 100 \cdot \frac{EPI_j - \min(EPI)}{\max(EPI) - \min(EPI)}$$

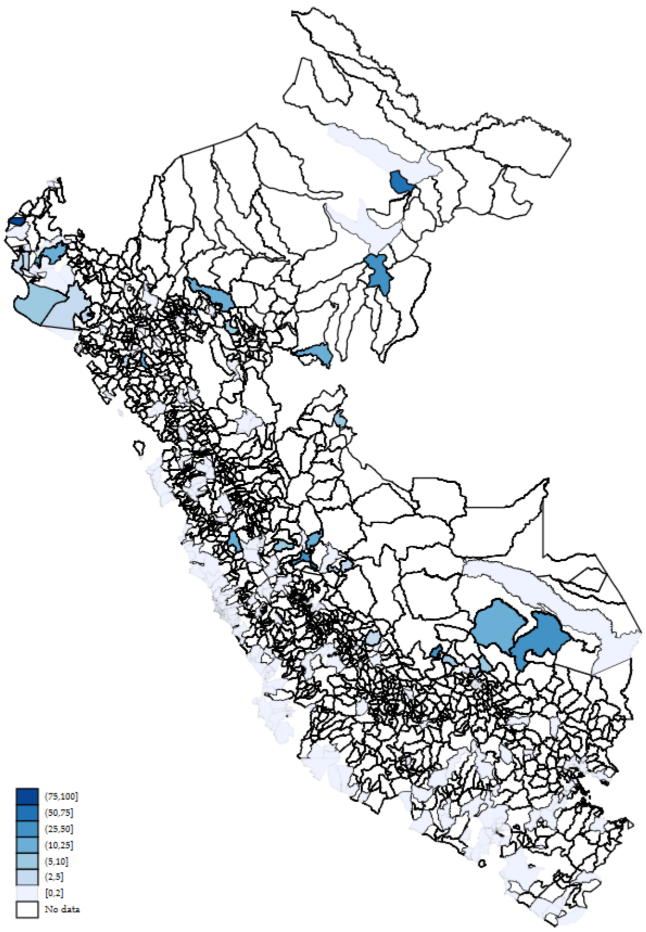
The darker blue areas indicate districts where the relative deforestation pressure, adjusted for export growth, is highest. These districts are primarily concentrated in the Amazon region, particularly in departments such as Loreto, Ucayali, and Madre de Dios, where rapid export growth has coincided with significant deforestation. In contrast, the coastal regions, including departments such as Lima, Ica, and Piura, exhibit predominantly lower EPI values, as shown by the lighter shades or absence of coloration. This reflects the historically lower levels of deforestation in these areas, likely due to their arid climate and the dominance of urban and agricultural export activities that exert less pressure on forested land.

The visualization underscores the heterogeneous nature of deforestation and export dynamics, with stark contrasts between the Amazon and coastal regions. This descriptive overview sets the stage for a more granular analysis of the EPI. In the following sections, we will examine each variable that constitutes this index—deforestation and export growth—individually. This will allow us to better understand the underlying factors contributing to the observed spatial patterns.

4.3 Export Growth and Decline

Figure 6 illustrates the spatial distribution of export growth and decline across Peruvian districts. Districts experiencing export growth are highlighted in darker shades, while those with declining exports are represented in lighter tones, measured as the variation between the first three years of the sample and the last three ones, as explained in the previous subsection. This visualization provides an initial perspective on the country's economic dynamics, showcasing how trade activities vary geographically. Notably, the coastal and southern region

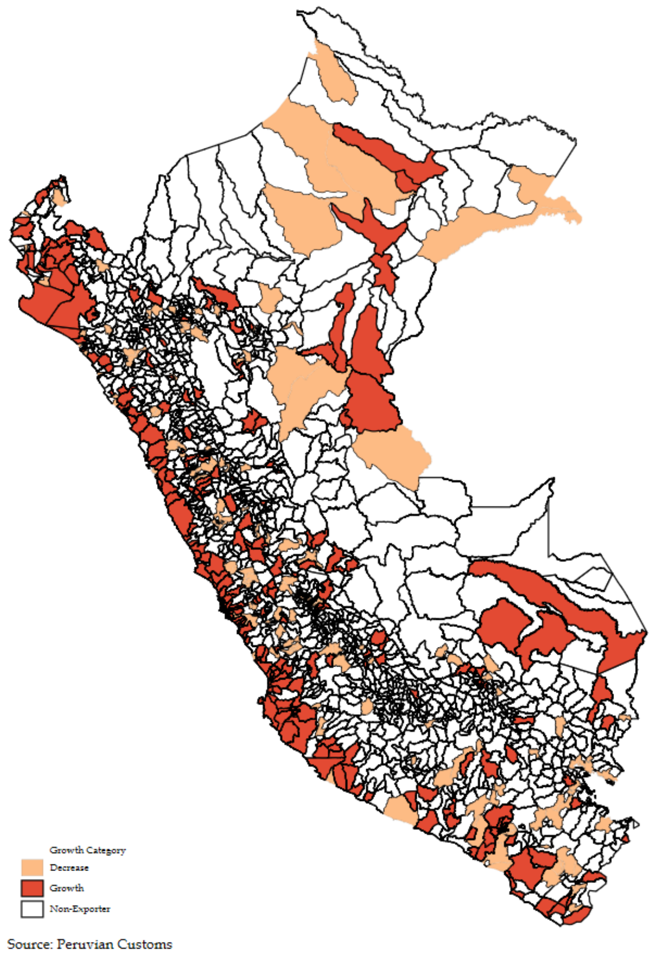
Figure 5: Relationship Between Deforestation and Export Growth



Source: MAPBIOMAS and Peruvian Customs

in general exhibit significant export growth, which may reflect the role of ports, export-oriented activities and more generally better physical infrastructure in these regions, in line with regional studies on the matter (see, for example, Mesquita Moreira et al. (2013)). In contrast, regions like Amazonas and Huánuco display fewer areas of export growth, indicating a varied economic landscape.[6]

Figure 6: Export Growth and Decline Across Districts in Peru



4.4 *Accumulated Deforestation*

Figures 7 and 8 present accumulated deforestation data from two sources: the Ministry of Environment (MINAM) and MapBiomas, respectively. Both maps highlight areas with significant deforestation, predominantly in Peru's Amazon regions, such as Loreto, Ucayali, and Madre de Dios. Utilizing data from these distinct sources offers a comprehensive understanding of deforestation trends, revealing potential discrepancies or consistencies between datasets. Darker regions indicate higher levels of accumulated deforestation, suggesting intense land conversion activities, possibly due to agriculture, mining, and other economic pressures.

[6]More detailed maps of the spatial distribution of export growth can be seen in Appendix Figures A4a and A4b.

Figure 7: Accumulated Deforestation According to the Ministry of Environment (MINAM)

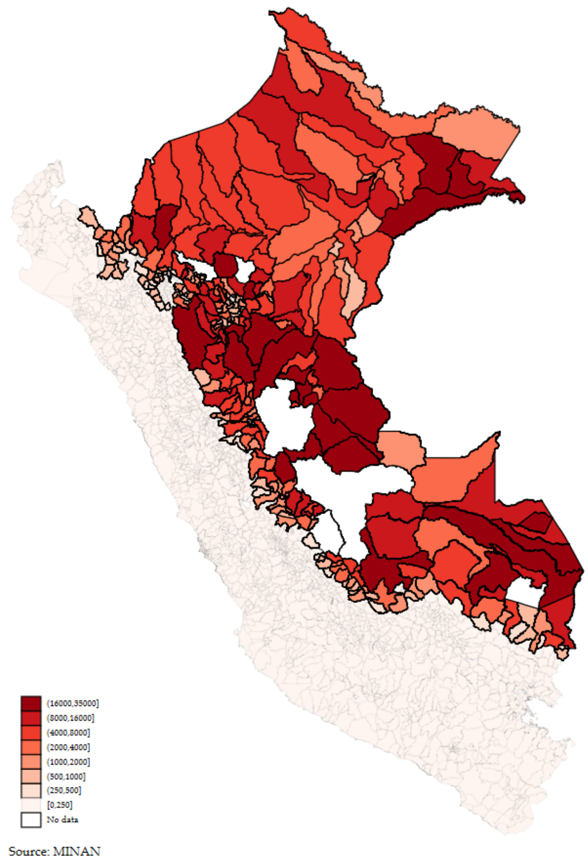
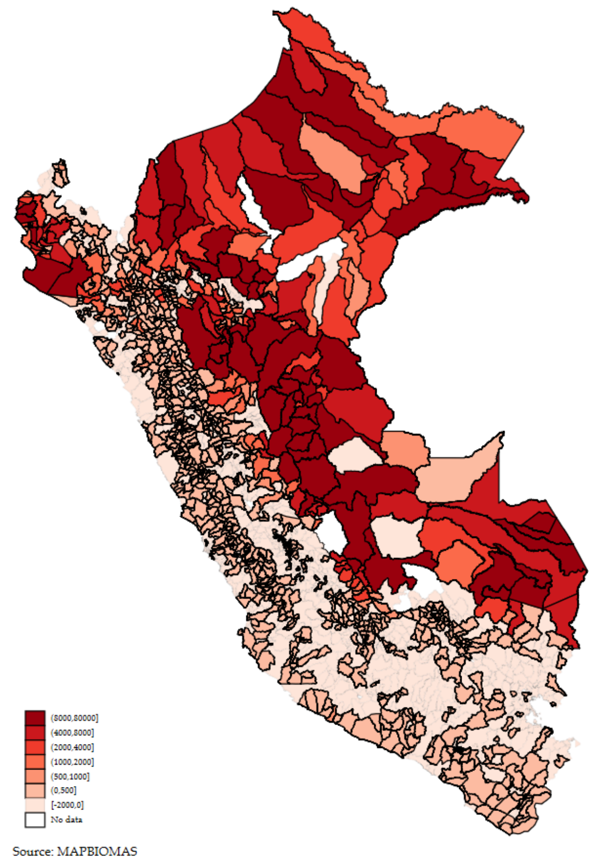


Figure 8: Accumulated Deforestation According to MapBiomas



In addition to deforestation, the MapBiomas dataset reveals regions where reforestation or natural regrowth has occurred, indicated by an increase in forested hectares. These areas, although less extensive than those affected by deforestation, suggest efforts in forest recovery or shifts in land use practices that favor regrowth. Such regions could be part of reforestation initiatives, natural regeneration following land abandonment, or community-led conservation practices.

4.5 Average Export Growth Rate

The spatial patterns in Figure 9 reveal that districts with higher average export growth rates are notably concentrated in certain regions, such as San Martín, Piura, and Cajamarca. These areas, marked by the darkest shades, suggest zones of economic dynamism potentially linked to increased trade activities. This trend aligns with the presence of agricultural or mining exports in these districts, reflecting how regional economic strengths contribute unevenly to national export growth. Additionally, this spatial variation emphasizes the distinct economic roles that different districts play, providing insights for targeted regional development policies.

5. Econometric Approach

As stated in the introduction, the econometric strategy employs a shift-share instrumental variable approach to address the potential endogeneity between trade and deforestation (Autor, Dorn and Hanson (2016); Borusyak, Hull and Jaravel (2024)). The primary focus is on disentangling the causal impact of exports on deforestation at the district level. The model specifications include:

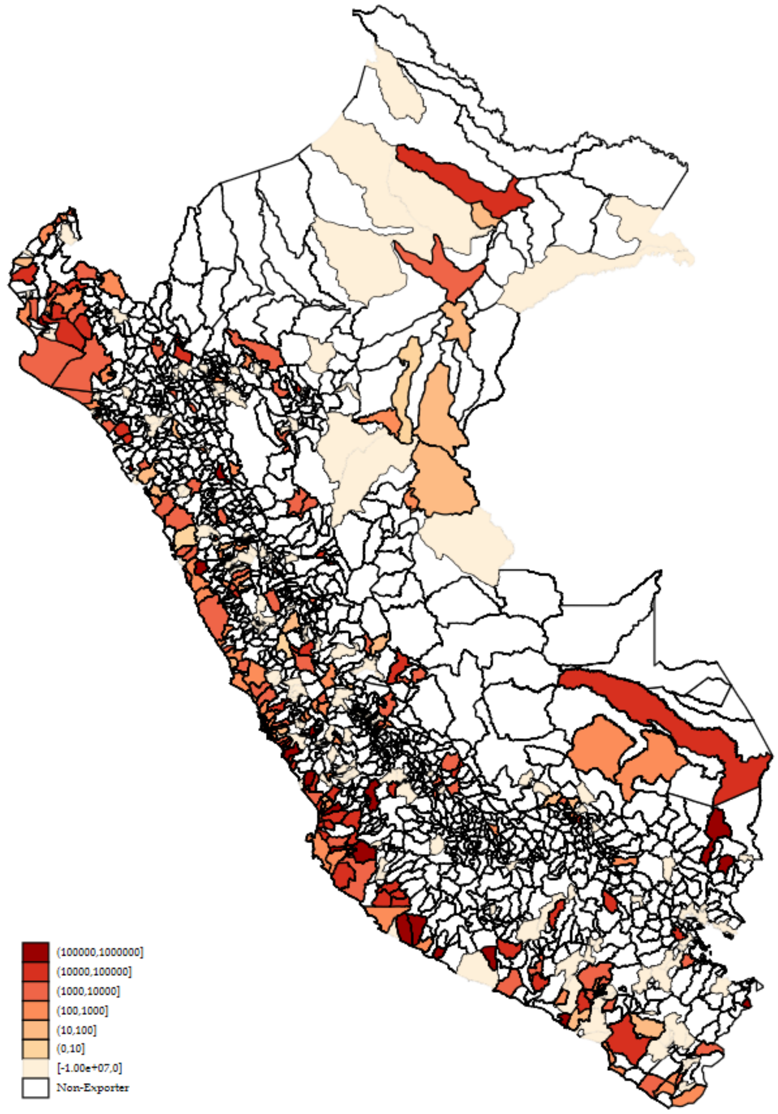
1. **Two-Way Fixed Effects (TWFE)** regressions for baseline comparison.
2. **Instrumental Variables (IV)** regressions using the shift-share instrument.
3. **Fixed Effects**: Year and province-level fixed effects are included to account for unobserved heterogeneity.
4. **Clustered Standard Errors**: Errors are clustered at the province level to address potential serial correlation in the panel data.

We also examine lagged effects ($t-1, t-2, t-5$) to capture the dynamic temporal impact of trade on deforestation.

5.1 First Stage: Instrument Construction

Following the approach of Borusyak, Hull, and Jaravel (2022; 2024) and Goldsmith-Pinkham, Sorkin, and Swift (2020), the shift-share instrument is constructed using district-level GDP shares and global demand shocks. Specifically, the instrument captures exogenous variation in export demand by interacting district-specific initial GDP

Figure 9: Average Export Growth Rate by District



Source: Peruvian Customs

shares with global export demand, excluding Peru and Latin America and the Caribbean (LAC) to avoid endogeneity. The instrument is constructed as follows:

$$IV_{jt} = \sum_{s} \left(\frac{GDP_{j,1995-1998}}{GDP_{total,1995-1998}} \right) \times \text{Global Demand}_{s,t} \tag{1}$$

Where IV_{jt} represents the shift-share instrument for district j in year t, constructed by interacting the initial GDP share of district j during the base period (1995-1998) with the global export demand for sector s in year t. The global demand variable is calculated by aggregating worldwide demand for exports across all regions, excluding Peru and LAC. This ensures that the instrument captures exogenous demand shocks while reducing endogeneity concerns.

The external demand data are sourced from the BACI dataset, while the GDP shares are calculated using district-level GDP projections. The instruments are constructed separately for different sectors and types of goods (e.g., value vs. weight) to account for heterogeneous impacts across product categories. The calculation of sector-specific instruments follows:

$$IV_{j,s,t} = \left(\frac{GDP_{j,1995-1998}}{GDP_{total,1995-1998}} \right) \times \text{Global Demand}_{s,t} \tag{2}$$

Where s represents different sectors such as agriculture, manufacturing, and mining. Each sector's global demand is projected onto the districts using the share of GDP to capture the differential exposure of districts to global demand shocks across sectors.

5.2 First Stage: Econometric Model

To estimate the impact of the instrumental variable on the endogenous variable (exports), we run the following econometric model for the first stage:

$$\ln(Exp_{jt}) = \alpha_0 + \alpha_1 \ln(IV_{jt}) + \beta_1 \ln(GDP_{jt}) + \beta_2 \ln(Area_j) + \gamma_p + \theta_t + \epsilon_{jt} \tag{3}$$

where Exp_{jt} represents exports in district j at time t, IV_{jt} is the previously explained instrument. The specification includes district GDP (GDP_{jt}) as a control, as well as district Area ($Area_j$), province (γ_p) and year (θ_t) fixed effects.

5.3 Second Stage: Estimation of Trade Impact

The second stage estimates the impact of trade on deforestation by regressing the deforestation and forest cover variables on the instrumented export levels. The econometric model is specified as follows:

$$ln(Y_{jt}) = \beta_0 + \beta_1 \widehat{\ln(Exp_{jt})} + \beta_2 \ln(GDP_{jt}) + \beta_3 \ln(Area_j) + \gamma_p + \theta_t + \epsilon_{jt} \tag{4}$$

where Y_{jt} represents our forest outcomes (either tree cover or deforestation) in district j at time t. The main independent variable $\widehat{\ln(Exp_{jt})}$ is the predicted value of exports from the first stage. As in the first stage, we control for district GDP and district Area and include province and year fixed effects to account for time-invariant district characteristics and common temporal shocks.

This research design follows recent methodological advances in the shift-share literature (Borusyak et al., 2022; Goldsmith-Pinkham et al., 2020). The validity of our approach relies on the exogeneity of national export growth rates to district-specific shocks, conditional on our controls and fixed effects. To explore sectoral heterogeneity, we also estimate specifications that decompose the effects by major export sectors (agriculture, manufacturing, and mining).

6. Results

Table 1 presents the results of the two-way fixed effects (TWFE) and the Shift-Share IV (IV-SS) regressions analyzing the relationship between export activity and deforestation, using deforestation data from MapBiomas. As previously stated, the analysis incorporates fixed effects at the year and provincial levels, with standard errors clustered at the provincial level to account for spatial correlation.

The results highlight the varying relationship between export activity and deforestation, depending on the estimation method. In the TWFE specification, presented in column (1) and (3), the results highlight a 3% decrease in total forest land for each 1% increase in exports, meanwhile, the results for deforestation are not statistically significant. However, when instrumenting exports using the IV-SS approach, the coefficient becomes positive and statistically significant for deforestation in column (4). This result suggests that increased export activity is associated with higher rates of deforestation when addressing potential endogeneity in the export variable. The IV-SS specification for total forest land in column (2) also reveals a negative and significant coefficient for exports, indicating that higher export activity is correlated with forest loss.[7]

Peru exhibits significant heterogeneity across its geographic regions, particularly between its highlands, lowlands, and coastal areas. To account for these regional differences, we estimate a specific model that evaluates the effects of export activity on deforestation within each distinct region. This approach allows us to capture and contrast the unique deforestation patterns across the Selva, Sierra, and Costa.

The results, presented in Table 6, reveal notable regional variations. In the Selva region, export activity shows a positive and statistically significant association with deforestation. The coefficient of 0.128 suggests that higher levels of exports in this region may lead to increased rates of forest loss, likely due to factors such as agricultural expansion or extractive industries. In the same sense, the Sierra region exhibits a weaker positive relationship between exports and deforestation, with a coefficient of 0.0820 which indicates a less strong link between the two variables in this particular region.

Turning to the Costa region, the table reveals no statistically significant effect of exports on the rate of deforestation. Meanwhile, it shows a decrease in the total forest land associated with higher export activity, with a coefficient of -0.162 that is not reflected in the other two regions. This result suggests that the relationship

[7] The results are highly robust to the utilization of MINAM as the source of the deforestation data, as shown in table A1.

Table 1: Effect of exports on deforestation

	Ln. Total Forest Land (MapBiomas)		Ln. Total Deforestation (MapBiomas)	
	TWFE	IV-SS	TWFE	IV-SS
Ln. 1+Exports in t	-0.0302***	-0.0648*	-0.00301	0.0486**
	(0.00713)	(0.0383)	(0.00470)	(0.0246)
Ln. GDP per Capita in t	-0.0341	0.101	0.0334	-0.171
	(0.115)	(0.145)	(0.0769)	(0.109)
Ln. Area	0.998***	1.019***	0.504***	0.476***
	(0.0670)	(0.0773)	(0.0475)	(0.0533)
Observations	33,042	33,042	19,053	19,053
R-squared	0.800	0.262	0.629	0.089
F.E. Year	Yes	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes	Yes
Region	Full	Full	Full	Full

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parentheses.

between exports and forest cover may differ across regions, with the Costa region showing a distinct pattern compared to the Selva and Sierra that might be linked with the specific exporting pattern of each region, as we will analyze later.

Table 3 explores the relationship between export activity and forest land across Peru's regions, distinguishing between districts with and without an environmental office as reported by the National Registry of Municipalities (RENAMU). The presence of an environmental office serves as a proxy for local institutional capacity and environmental governance.

The results indicate nuanced regional effects. At the national level, export activity is associated with a significant reduction in total forest land in districts with an environmental office. However, the magnitude and significance of this effect vary by region. For the Selva (Amazonian) region, there is no statistically significant relationship, suggesting that the presence of an environmental office might moderate the impact of exports on forest loss, possibly by enforcing conservation policies or providing regulatory oversight. In contrast, the Costa region shows a stronger negative relationship which could reflect weaker institutional enforcement despite the presence of such offices or export-driven pressures on non-forested ecosystems converted for trade-related activities. Interestingly, in the Sierra, no significant effect is observed, potentially pointing to lesser deforestation pressures in high-altitude agricultural or mining zones.

For districts without an environmental office, the national-level coefficient remains negative but is not statistically significant. However, in the Costa region, export activity again shows a significant and substantial negative effect on forest land. This suggests that, in this region, the lack of environmental governance exacerbates the

Table 2: Effect of exports on deforestation, by region

	Ln. Total Forest Land (MapBiomas)			Ln. Total Deforestation (MapBiomas)		
	IV-SS	IV-SS	IV-SS	IV-SS	IV-SS	IV-SS
Ln. 1+Exports in t	0.000489	0.00300	-0.162***	0.128*	0.0820**	-0.0164
	(0.0293)	(0.0577)	(0.0511)	(0.0689)	(0.0318)	(0.0304)
Ln. GDP per Capita in t	-0.333**	0.00507	0.552	-0.949***	-0.204	0.189
	(0.142)	(0.201)	(0.333)	(0.280)	(0.135)	(0.212)
Ln. Area	1.296***	0.865***	1.275***	0.546***	0.417***	0.626***
	(0.0592)	(0.0910)	(0.194)	(0.0674)	(0.0580)	(0.131)
Observations	3,420	20,774	7,568	1,510	12,599	4,504
R-squared	0.797	0.186	0.168	0.081	0.022	0.148
F.E. Year	Yes	Yes	Yes	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes	Yes	Yes	Yes
Region	Selva	Sierra	Costa	Selva	Sierra	Costa

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses.

Table 3: Effect of Exports on Total Forest Land, Accounting for Environmental Office Presence

	Ln. Total Forest Land (MapBiomas)			
	IV-SS	IV-SS	IV-SS	IV-SS
Ln. 1+Exports of Districts with Env. Office	-0.0652**	-0.00612	-0.0107	-0.154***
	(0.0329)	(0.0248)	(0.0477)	(0.0478)
Ln. 1+Exports of Districts without Env. Office	-0.0644	0.0102	0.0198	-0.171***
	(0.0462)	(0.0416)	(0.0738)	(0.0556)
Ln. GDP per Capita in t	0.101	-0.334**	0.0102	0.550
	(0.145)	(0.143)	(0.199)	(0.336)
Ln. Area	1.019***	1.296***	0.865***	1.275***
	(0.0774)	(0.0591)	(0.0905)	(0.195)
Observations	33,042	3,420	20,774	7,568
R-squared	0.262	0.796	0.182	0.160
F.E. Year	Yes	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes	Yes
Region	Full	Selva	Sierra	Costa

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses.

vulnerability of forest land to export-driven pressures. For the Selva and Sierra regions, the lack of statistical significance might indicate either stronger natural resistance to deforestation in less-regulated areas or limitations in institutional reach affecting the data's explanatory power.

Table 4 examines the impact of export activity on deforestation rates, incorporating the same distinction between districts with and without environmental offices. The findings reinforce the importance of institutional capacity in moderating deforestation pressures.

In districts with an environmental office, export activity shows no significant association with deforestation at the national level. Regionally, the Selva and Costa exhibit contrasting patterns. In the Selva, exports in districts with environmental offices are associated with an increase in deforestation, although not statistically significant. This could reflect the limitations of local institutions in mitigating deforestation pressures from agricultural expansion or resource extraction activities that dominate the Amazon region. Conversely, in the Costa, no significant relationship is found, indicating that forest loss may be less sensitive to institutional governance in this region due to different land-use dynamics.

For districts without an environmental office, the findings are stark. At the national level, export activity is positively associated with deforestation. Regionally, the Selva shows a significant positive relationship, emphasizing the heightened vulnerability of forest ecosystems to export-driven pressures in the absence of governance structures. Similarly, the Sierra displays a positive and significant association, suggesting that exports in this region, even in the absence of dense forests, drive land-use changes that contribute to deforestation.

Table 4: Effect of Exports on Total Deforestation, Accounting for Environmental Office Presence

	Ln. Total Deforestation (MapBiomas)			
	IV-SS	IV-SS	IV-SS	IV-SS
Ln. 1+Exports of Districts with Env. Office	0.0329	0.0932	0.0559**	-0.0211
	(0.0211)	(0.0565)	(0.0272)	(0.0279)
Ln. 1+Exports of Districts without Env. Office	0.0648**	0.190**	0.107***	-0.0119
	(0.0288)	(0.0882)	(0.0383)	(0.0342)
Ln. GDP per Capita in t	-0.164	-0.977***	-0.187	0.189
	(0.107)	(0.281)	(0.133)	(0.211)
Ln. Area	0.476***	0.547***	0.419***	0.626***
	(0.0527)	(0.0647)	(0.0571)	(0.131)
Observations	19,053	1,510	12,599	4,504
R-squared	0.081	0.020	0.002	0.150
F.E. Year	Yes	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes	Yes
Region	Full	Selva	Sierra	Costa

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parentheses.

6.1 Heterogeneities and Mechanisms

Tables 5 and 6 examine how the effect of export activity on forest land and deforestation varies across districts with and without conserved areas. These areas, identified through the Registry of Communities affiliated with the TDC mechanism, represent community-led conservation efforts and serve as a proxy for environmental stewardship. The analysis highlights how conservation mechanisms moderate the environmental impacts of trade and reveals regional heterogeneities that policymakers must consider.

In districts with conserved areas, the results indicate that conservation mechanisms partially mitigate the adverse impacts of export activity on forest land. While export growth does not appear to drive statistically significant forest loss, deforestation pressures remain. This suggests that while community-led conservation initiatives buffer against trade-induced land-use changes, they are not entirely effective in halting ongoing deforestation. These findings underscore the importance of conservation mechanisms as a crucial, albeit imperfect, defense against the environmental costs of trade.

Table 5: Effect of Exports with and without Conserved Areas on Total Forest Land (MapBiomas)

	Ln. Total Forest Land (MapBiomas)			
Variables	IV-SS	IV-SS	IV-SS	IV-SS
Ln. 1+Exports of Districts with Conserved Area	0.0695	0.00682	0.493	-
	(0.0634)	(0.0512)	(0.359)	
Ln. 1+Exports of Districts without Conserved Area	-0.0683*	-0.00116	-0.00307	-0.162***
	(0.0381)	(0.0327)	(0.0578)	(0.0511)
Ln. GDP per Capita in t	0.109	-0.331**	0.0178	0.552
	(0.145)	(0.149)	(0.201)	(0.333)
Ln. Area	1.006***	1.294***	0.861***	1.275***
	(0.0788)	(0.0657)	(0.0911)	(0.194)
Observations	33,042	3,420	20,774	7,568
R-squared	0.260	0.797	0.170	0.168
F.E. Year	Yes	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes	Yes
Region	Full	Selva	Sierra	Costa

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parentheses.

By contrast, districts without conserved areas face significantly higher environmental pressures. The results show a pronounced negative relationship between exports and forest land, alongside increased deforestation rates. The absence of institutional or community-based conservation frameworks leaves these districts particularly vulnerable to land-use changes driven by agricultural expansion, infrastructure development, and other trade-related activities. This is especially concerning in regions where governance capacity is weak or conservation enforcement is limited.

The results also reveal meaningful regional variation, reflecting the uneven distribution of conserved areas and regional differences in trade exposure:

- In the Selva (Amazonian) region, districts without conserved areas exhibit the most pronounced deforestation impacts. Given the ecological sensitivity of the Selva, this finding points to the urgent need for expanding conservation mechanisms and strengthening enforcement. Community participation and stewardship programs could be scaled up to enhance the protective effects observed in districts with conserved areas.
- In the Sierra (Andean) region, the results show mixed effects, with conservation mechanisms playing a role in limiting forest loss but still falling short of preventing deforestation entirely. The Sierra's unique combination of land pressures and export activities suggests that more tailored conservation approaches, integrating both agricultural and community interests, may be needed to address these vulnerabilities.
- The Costa (Coastal) region stands out as particularly exposed, as districts in this region largely lack conserved areas altogether. This absence of institutional or community-based protection mechanisms exacerbates the environmental consequences of trade. Policymakers could focus on developing alternative strategies tailored to the Costa's ecological and economic dynamics, such as incentivizing private conservation efforts or introducing region-specific sustainability programs.

Table 6: Effect of Exports with and without Conserved Areas on Total Deforestation (MapBiomas)

	Ln. Total Deforestation (MapBiomas)			
Variables	IV-SS	IV-SS	IV-SS	IV-SS
Ln. 1+Exports of Districts with Conserved Area	0.0766	-0.0452	0.436	-
	(0.0621)	(0.0995)	(0.442)	
Ln. 1+Exports of Districts without Conserved Area	0.0480*	0.166**	0.0788**	-0.0164
	(0.0245)	(0.0789)	(0.0320)	(0.0304)
Ln. GDP per Capita in t	-0.170	-1.014***	-0.196	0.189
	(0.108)	(0.295)	(0.135)	(0.212)
Ln. Area	0.475***	0.581***	0.418***	0.626***
	(0.0538)	(0.0768)	(0.0581)	(0.131)
Observations	19,053	1,510	12,599	4,504
R-squared	0.089	0.022	0.016	0.148
F.E. Year	Yes	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes	Yes
Region	Full	Selva	Sierra	Costa

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses.

The findings from Tables 5 and 6 highlight the critical role of conservation mechanisms in moderating the environmental impacts of trade. However, the partial effectiveness observed suggests that current frameworks are insufficient to fully counteract trade-induced land-use changes.

In trade-exposed districts, particularly those without conserved areas, expanding conservation mechanisms—such as community-led initiatives, enforcement capacity, and payment-for-ecosystem services—may be essential to mitigating environmental damage. Aligning trade policies with conservation goals could further amplify these effects. For instance, promoting sustainable supply chains, certification schemes, and eco-friendly trade practices could incentivize producers to adopt practices that reduce forest loss and deforestation while maintaining economic growth.

Table 7 builds on these findings by examining the broader environmental pollution indicators associated with export activity. The results highlight significant increases in auto-reported pollution problems, particularly those related to deforestation, noise, and wastewater. Export activity is strongly associated with higher rates of forest damage and pollution, underscoring the environmental trade-offs linked to economic growth. These results align with the patterns observed in Tables 5 and 6, where districts lacking conserved areas or institutional protections appear more vulnerable to the environmental pressures of exports.

Table 7: Effect of Exports on Various Environmental Pollution Indicators

	Reported pollution problems	Pollution: Deforestation (Forest Damage)	Pollution: Noise	Pollution: Wastewater
Ln. 1+Exports in t	0.0186***	0.0108**	0.0772***	0.0763***
	(0.00202)	(0.00479)	(0.00462)	(0.00897)
Ln. GDP per Capita in t	-0.00750	-0.0432	-0.00962	-0.0432
	(0.0127)	(0.0397)	(0.0281)	(0.0375)
Ln. Area				
Observations	20,145	25,455	25,455	25,455
R-squared	-0.067	-0.001	-0.359	-0.160
F.E. Year	Yes	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes	Yes

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parentheses.

Interestingly, Table 8 shifts the focus to the role of planning and environmental management instruments. It reveals that export activity is positively associated with the presence of development and management plans, including urban and rural development plans and environmental management strategies. While these results suggest a growing recognition of the need for institutional responses to mitigate export-driven environmental challenges, the effectiveness of these plans remains uncertain. The positive association between exports and management instruments may reflect an adaptive response to increasing environmental pressures, but it also highlights the need for robust implementation and enforcement mechanisms.

Table 8: Effect of Exports on Management and Development Instruments

	Territorial Conditioning Plan	Urban Development Plan	Rural Development Plan	Environmental Management Plan
Ln. 1+Exports in t	0.0130***	0.0290***	0.00418***	0.0238***
	(0.00207)	(0.00311)	(0.00129)	(0.00241)
Ln. GDP per Capita in t	0.00176	0.00638	-0.0151	0.00638
	(0.0109)	(0.0195)	(0.0105)	(0.0137)
Ln. Area				
Observations	21,781	21,781	21,781	19,949
R-squared	-0.039	-0.071	-0.003	-0.066
F.E. Year	Yes	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes	Yes

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parentheses.

Together, Tables 5, 6, 7, and 8 paint a comprehensive picture of the multifaceted relationship between exports and environmental outcomes. While exports drive economic growth, they also exacerbate environmental degradation and pollution, particularly in districts without adequate conservation mechanisms or planning instruments. The findings emphasize the importance of integrating environmental considerations into trade policies and regional development strategies. Policymakers might prioritize the expansion and enforcement of conservation frameworks, alongside the implementation of effective management plans, to further balance economic growth with environmental sustainability.

6.2 Sectoral Analysis

This section introduces a detailed subsectoral analysis based on Tables 9, 10, and 11, which focus on the specific environmental impacts of different export categories, including agriculture, mining, manufacturing, and other goods. By examining their respective contributions to changes in forest land, deforestation, and agricultural land, this analysis offers a more granular understanding of the mechanisms linking trade activities to environmental outcomes.

Agricultural exports exhibit a clear pattern of reducing total forest land while simultaneously increasing agricultural land. This trend is coherent with the conversion of forested areas into farmland to meet export demands. The strong positive association between agricultural exports and agricultural land underscores the direct impact of this sector on land-use change. However, this expansion comes at the expense of forest ecosystems, as it is also shown by the increase in the deforestation rate associated with agricultural exports.

In the other hand, mining exports (shown in Table 10) present a different dynamic. While not directly linked to agricultural expansion, mining activities are strongly associated with increased deforestation, likely due to

Table 9: Effect of Different Export Categories on Forest, Deforestation, and Agricultural Land (MapBiomas)

	Ln. Total Forest Land (MapBiomas)	Ln. Total Deforestation (MapBiomas)	Ln. Total Agriculture Land (MapBiomas)
Ln. GDP per Capita in t	0.0556	-0.135	-0.377***
	(0.129)	(0.0966)	(0.0664)
Ln. Area	1.002***	0.488***	0.513***
	(0.0731)	(0.0492)	(0.0359)
Ln. Agr Exports in t	-0.0885*	0.0672*	0.215***
	(0.0512)	(0.0359)	(0.0298)
Observations	33,042	19,053	33,015
R-squared	0.247	0.100	-0.177
F.E. Year	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes
Region	Full	Full	Full

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parentheses.

land clearing for extraction sites, infrastructure, and related development. The data also suggest an impact on agricultural land that might come from spillovers from this sector's economic activity, since it is one of the most dynamic sectors in Peru.

The manufacturing sector shows a subtler but still notable relationship with environmental change. Manufacturing exports are linked to reductions in forest land and increases in agricultural land, suggesting another indirect influence on land-use dynamics. Meanwhile, exports of other goods display a more nuanced impact, with insignificant forest loss but increases in agricultural land.

6.3 *Resources Factor Intensity*

To further understand the heterogeneity in the relationship between trade and deforestation, we employed the Revealed Factor Intensity Index (RFII) to classify products into categories based on their factor intensities. Specifically, we leveraged the methodologies outlined by Shirotori, Tumurchudur, and Cadot (2010) and updated by Mclaren, Saygili, and Shirotori (2018), which provide a detailed dataset of RFII values for over 5,000 products classified at the HS-6 digit level. The RFII assigns a factor intensity value to each product by calculating the trade-weighted average of the endowment levels of countries that predominantly export the product. Three types of factor endowments are considered:

- Physical Capital: Measured by the capital stock per worker.
- Human Capital: Proxied by the average years of schooling.
- Arable Land: Represented as hectares of arable land per worker.

Table 10: Effect of Export Categories on Forest, Deforestation, and Agricultural Land (MapBiomas)

	Ln. Total Forest Land (MapBiomas)	Ln. Total Deforestation (MapBiomas)	Ln. Total Agriculture Land (MapBiomas)
Ln. GDP per Capita in t	0.147	-0.203	-0.600***
	(0.167)	(0.131)	(0.127)
Ln. Area	1.063***	0.437***	0.364***
	(0.0948)	(0.0705)	(0.0650)
Ln. Mining Exports in t	-0.223	0.181*	0.544***
	(0.137)	(0.0984)	(0.115)
Observations	33,042	19,053	33,015
R-squared	0.196	-0.036	-2.981
F.E. Year	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes
Region	Full	Full	Full

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses.

Table 11: Effect of Export Categories on Forest, Deforestation, and Agricultural Land (MapBiomas)

	Exports: Manufactured Goods			Exports: Other Goods		
	Ln. Total Forest Land (MapBiomas)	Ln. Total Deforestation (MapBiomas)	Ln. Total Agriculture Land (MapBiomas)	Ln. Total Forest Land (MapBiomas)	Ln. Total Deforestation (MapBiomas)	Ln. Total Agriculture Land (MapBiomas)
Ln. GDP per Capita in t	0.0875	-0.161	-0.455***	0.00201	-0.0904	-0.246***
	(0.140)	(0.104)	(0.0801)	(0.120)	(0.0809)	(0.0759)
Ln. Area	1.005***	0.487***	0.506***	0.972***	0.511***	0.585***
	(0.0739)	(0.0493)	(0.0394)	(0.0701)	(0.0426)	(0.0367)
Ln. Manuf. Exports in t	-0.0787*	0.0583**	0.192***			
	(0.0467)	(0.0294)	(0.0279)			
Ln. Other Exports in t				-0.432	0.315*	1.049***
				(0.281)	(0.167)	(0.283)
Observations	33,042	19,053	33,015	33,042	19,053	33,015
R-squared	0.257	0.092	-0.319	0.197	0.061	-1.428
F.E. Year	Yes	Yes	Yes	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes	Yes	Yes	Yes
Region	Full	Full	Full	Full	Full	Full

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses.

To construct the WAFIE, we first calculated the factor intensity for each product in the district's export basket. This was done by multiplying the factor intensity of each product by the district's total exports. The WAFIE for each district j in year t is then given by:

$$WAFIE_{jt} = \sum^{p \in P} NRI_{p,1995-1998} \times \text{Export}_{j,p,t}$$

Where $NRI_{p,1995-1998}$ is a number between 0 and 1 that represents the factor intensity of the product p calculated for the years between 1995 and 1998. This metric reflects the relative importance of resource-intensive products in a district's export portfolio. Similarly, we constructed the Weighted Average Factor Intensity Demand (WAFID) to measure the resource intensity of global demand for products exported by Perú. Given that we do not have direct district variation, the WAFID in year t is given by:

$$WAFID_t = \sum^{p \in P} NRI_{p,1995-1998} \times \text{Global Demand}_{p,t}$$

The WAFID serves as an aggregate measure of how resource-intensive global demand is for Peruvian exports. Finally, we used the WAFID to construct the instrument for the IV-SS estimation:

$$IV_{jt} = \left(\frac{GDP_{j,1995-1998}}{GDP_{total,1995-1998}} \right) \times \text{WAFID}_t$$

As in the previous subsections, the instrument exploits exogenous variations in global demand weighted by district-level economic activity.

Table 12 shows the results which revealed important insights about the role of weighted resource intensity in shaping the outcomes. For forest coverage, the results indicate a negative relationship between exports and total forest land. This finding underscores the broader environmental trade-offs associated with export-driven economic activity. The use of WAFIE, which captures the factor intensity of a district's export basket, highlights how areas more reliant on resource-intensive exports experience greater forest loss. This result becomes more pronounced when addressing endogeneity through the IV-SS model, suggesting that unobserved factors may exacerbate the environmental costs of export expansion. Importantly, this negative effect reflects a structural dynamic where resource extraction or expansion of export-oriented resource intensive activities contributes to forest clearing.

In the case of deforestation, the IV-SS results reveal a positive and significant effect of exports, even though this relationship is not apparent under the fixed effects model. Here, the weighted effect of resource intensity provides an important interpretation: the products that drive exports in these districts are not only associated with land use changes but also exhibit strong links to deforestation, likely through their reliance on land-intensive production processes. For agricultural land use, the results consistently show a strong positive relationship with exports, with the effect becoming more pronounced under the IV-SS specification. This highlights a clear mechanism through which exports drive land use changes: increased global demand for resource-intensive goods

Table 12: Impact on Forest, Deforestation, and Agricultural Land (MapBiomas)

	Ln. Total Forest Land		Ln. Total Deforestation		Ln. Total Agriculture Land	
	TWFE	IV-SS	TWFE	IV-SS	TWFE	IV-SS
Ln. 1+Exports in t	-0.0355***	-0.0751*	-0.00413	0.0564*	0.00845**	0.183***
	(0.00830)	(0.0443)	(0.00550)	(0.0286)	(0.00385)	(0.0246)
Ln. GDP per Capita in t	-0.0309	0.104	0.0358	-0.172	0.0989**	-0.494***
	(0.115)	(0.146)	(0.0769)	(0.109)	(0.0441)	(0.0822)
Ln. Area	0.999***	1.020***	0.505***	0.475***	0.561***	0.469***
	(0.0670)	(0.0776)	(0.0476)	(0.0535)	(0.0287)	(0.0397)
Observations	33,042	33,042	19,053	19,053	33,015	33,015
R-squared	0.800	0.263	0.629	0.088	0.759	-0.270
F.E. Year	Yes	Yes	Yes	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes	Yes	Yes	Yes

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parentheses.

incentivizes the conversion of forested areas into agricultural land. In this context, the WAFIE captures the structural composition of exports in each district, where higher intensities reflect a greater reliance on agricultural or extractive production. The positive association with agricultural land use therefore suggests that export growth, particularly in land-intensive sectors, is a key driver of land conversion.

The relevance of this weighted effect lies in its ability to quantify the underlying composition of export activities and link it to observed environmental outcomes. By incorporating factor intensity measures, the analysis moves beyond aggregate export growth to show that the type of goods exported matters significantly for forest conservation and land use. Districts with higher WAFIE values are disproportionately exposed to environmental pressures, as their export baskets are more reliant on resource extraction and land-intensive production. Furthermore, the use of global demand shocks (WAFID) as an instrument emphasizes the role of external forces—such as shifts in international market demand—in amplifying these effects.

To deepen the analysis of the relationship between trade and land-use outcomes, we further disaggregate exports into soft and intensive products. These categories are based on the RFII described earlier, which assigns a value between 0 and 1 to each product, reflecting its resource intensity. Specifically, we classify products as:

- **Soft Products**: Products with RFII values below the median, indicating lower reliance on resource-intensive production.
- **Intensive Products**: Products with RFII values the median, indicating lower reliance on resource-intensive production.

Using this classification, we construct two export measures for each district:

$$\text{Soft Exports}_{jt} = \sum_{p \in P_{\text{soft}}} \text{Export}_{j,p,t}, \quad \text{Intensive Exports}_{jt} = \sum_{p \in P_{\text{intensive}}} \text{Export}_{j,p,t}$$

where P_{soft} and $P_{\text{intensive}}$ represent the sets of products classified as soft and intensive, respectively.

Table 13 presents the TWFE results, showing the differential effects of soft and intensive exports on forest coverage, deforestation, and agricultural land use. Again, this framework allows us to control for time-invariant province characteristics and time-fixed shocks, while clustering standard errors at the provincial level to account for spatial correlation. The results highlight important heterogeneities in how soft and intensive products influence land use outcomes. For forest coverage, exports of intensive products are significantly associated with forest loss, while soft products show no statistically significant effect. This result aligns with expectations, as intensive products, by definition, require greater use of land or natural resources, contributing directly to forest clearing.

Table 13: Differential Impact of Soft and Intensive Exports

	Ln. Total Forest Land (MapBiomas)	Ln. Total Deforestation (MapBiomas)	Ln. Total Agriculture Land (MapBiomas)
Ln. 1+Exports in Soft Products	-0.00367	0.0153*	0.0136**
	(0.0128)	(0.00834)	(0.00674)
Ln. 1+Exports in Intensive Products	-0.0343***	-0.00915	0.00361
	(0.00861)	(0.00570)	(0.00434)
Ln. GDP per Capita in t	-0.0365	0.0162	0.0865*
	(0.115)	(0.0780)	(0.0441)
Ln. Area	0.997***	0.504***	0.561***
	(0.0672)	(0.0474)	(0.0289)
Observations	33,042	19,053	33,015
R-squared	0.800	0.630	0.760
F.E. Year	Yes	Yes	Yes
F.E. Provincia	Yes	Yes	Yes
Clust. per Provincia	Yes	Yes	Yes

Note: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

7. Conclusion

This study provides a comprehensive examination of the complex relationship between export activities and deforestation in Peru, revealing significant sectoral and regional heterogeneities. By employing a shift-share instrumental variables approach, the analysis isolates the causal effects of exports on forest loss, uncovering critical mechanisms that drive land-use changes. The findings demonstrate that export growth, particularly in agriculture and mining, exerts substantial pressure on forest ecosystems, especially in the Amazonian Selva. In contrast, manufacturing and non-resource-intensive exports show a less direct impact, highlighting the diversity of environmental consequences linked to trade.

Regional dynamics are particularly striking. The Selva region, characterized by its ecological sensitivity, experiences pronounced deforestation linked to agricultural expansion and resource extraction. Meanwhile, the Costa region exhibits lower forest pressures but reveals a distinctive pattern where export growth primarily affects non-forested ecosystems. The Sierra, with its unique land-use patterns, displays a less intense but still notable interaction between exports and environmental outcomes. This heterogeneity underscores the need to interpret the trade-environment nexus through a geographically nuanced lens.

Institutional capacity emerges as a pivotal factor in moderating the environmental impacts of trade. Districts with conservation mechanisms or environmental offices experience a tempered relationship between exports and deforestation. However, the effectiveness of these measures varies, with governance limitations often leaving districts vulnerable to land-use changes. The presence of community-led conservation initiatives in some areas suggests a partial buffering effect, though these efforts alone are insufficient to halt deforestation trends driven by global market demands.

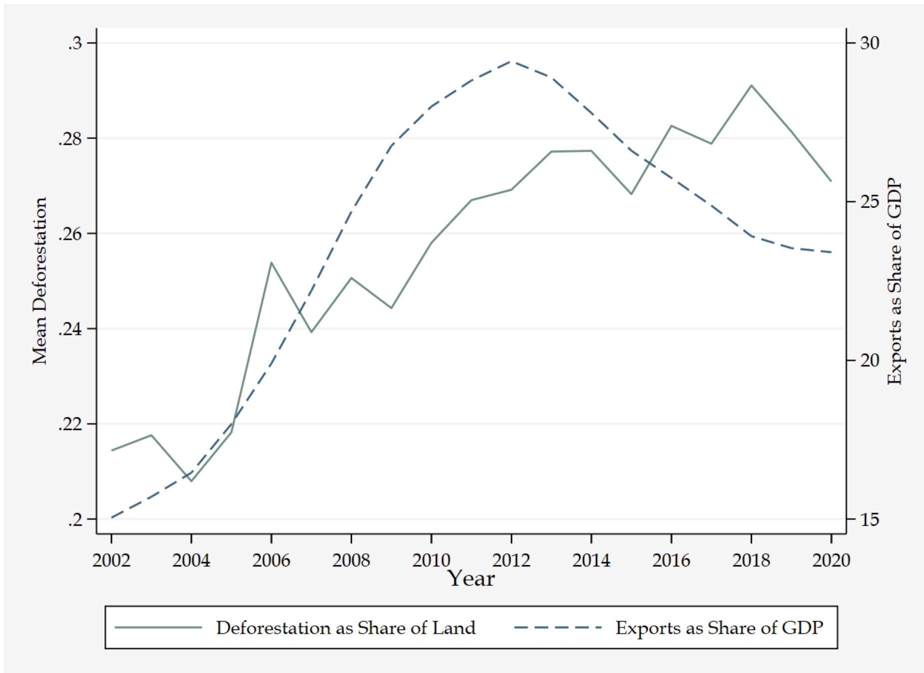
The analysis also emphasizes the structural characteristics of Peru's export sectors. Agricultural exports directly expand the agricultural frontier at the expense of forest cover, while mining activities create deforestation through land clearing and associated infrastructure development. These findings illustrate how the composition of export baskets—and their resource intensity—can shape land-use dynamics in fundamental ways.

In conclusion, this study contributes to a deeper understanding of how international trade influences deforestation in a resource-rich, trade-dependent economy. By unraveling the causal mechanisms and highlighting the heterogeneities across regions and sectors, it offers a nuanced perspective on the trade-offs between economic growth and environmental sustainability. These insights enrich the broader discourse on the environmental costs of globalization, shedding light on the challenges faced by nations with valuable but vulnerable ecosystems.

8. Appendix

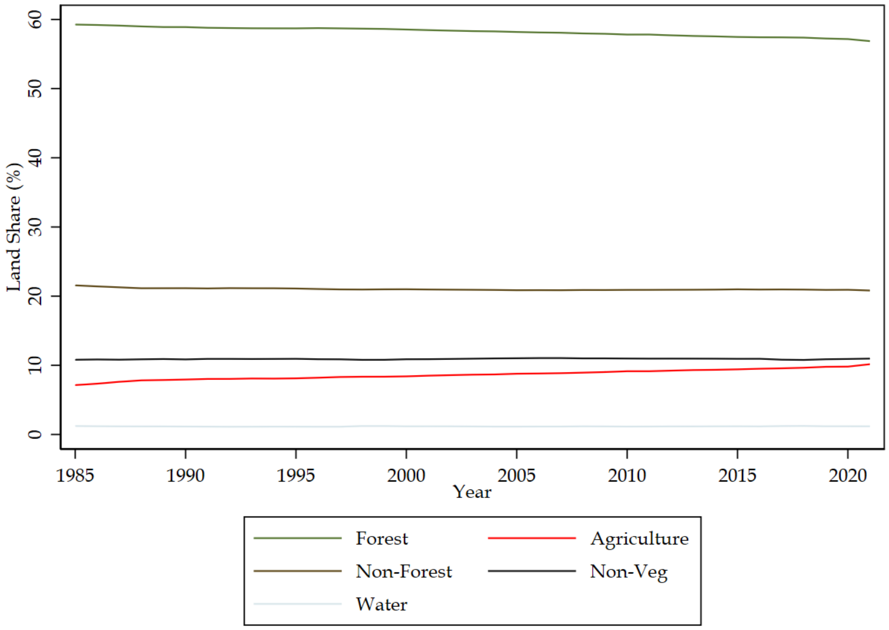
A1 Deforestation as share and Exports Over Time

Figure A1: Deforestation as share and Exports Over Time



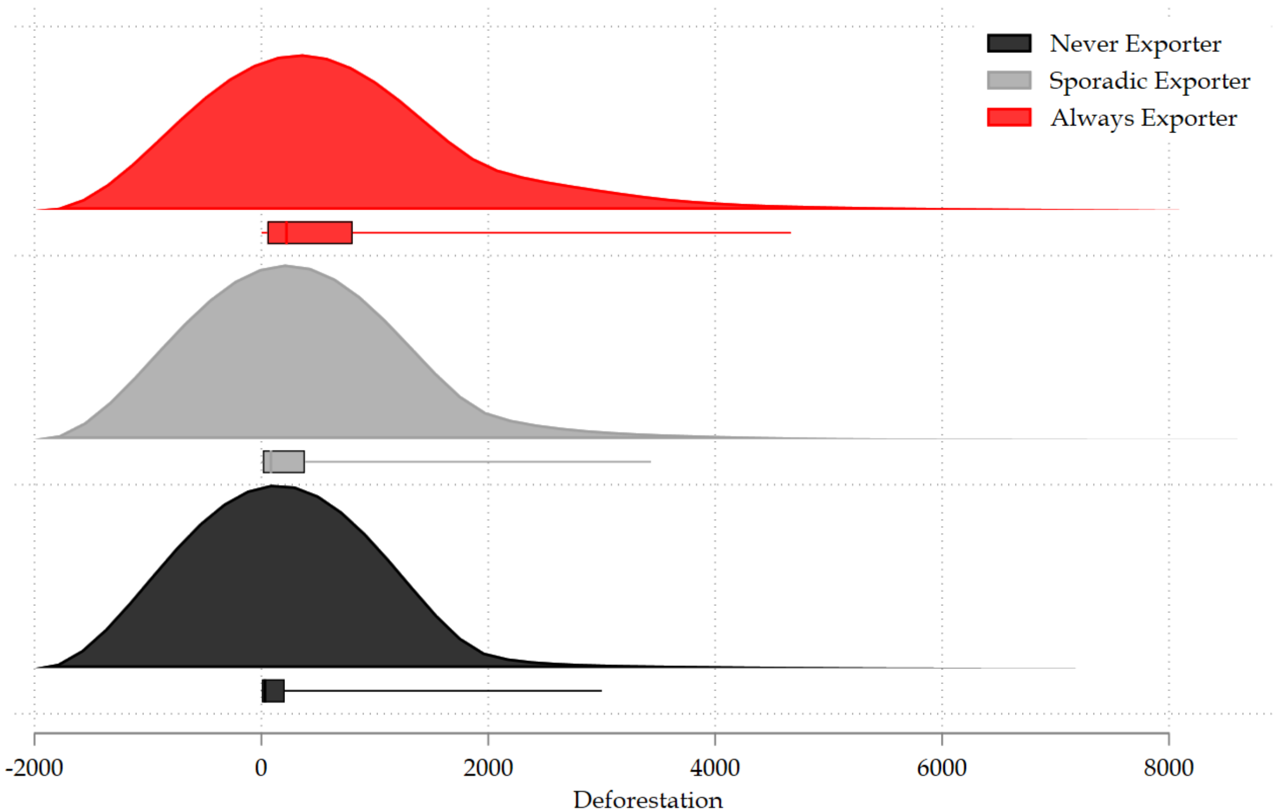
A2 Land Shares Over Time

Figure A2: Land Shares Over Time



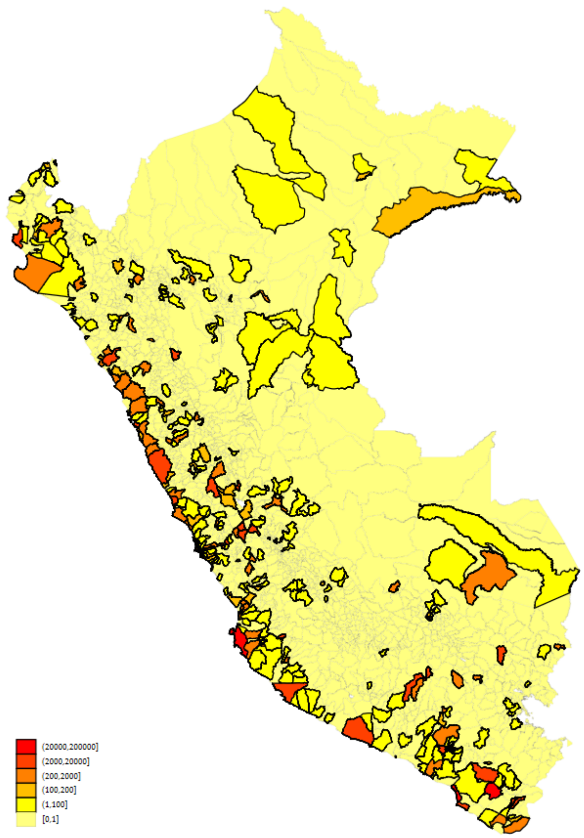
A3 Relationship Between District Export Condition and Deforestation

Figure A3: Relationship Between District Export Condition and Deforestation



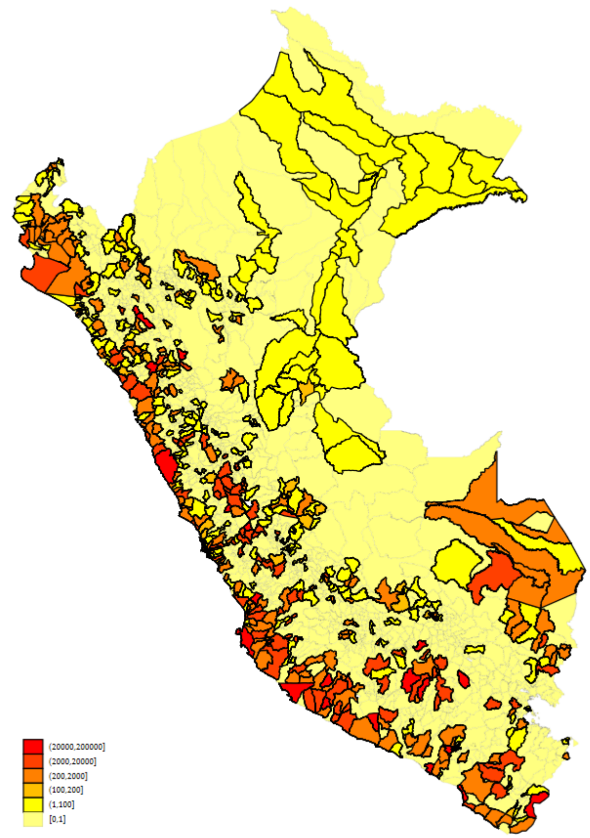
A4 Exports per Capita

Figure A4a: Exports per Capita in 1999



Source: Peruvian Customs. Year 1999 or 2000.

Figure A4b: Exports per Capita in 2017



Source: Peruvian Customs. Year 2016 or 2017.

A5 Alternative Specification using MINAM Data

Table A1: Effect of exports on deforestation

	Ln. Total Deforestation (MINAM)	
Variables	TWFE	IV-SS
Ln. GDP per Capita in t	0.133	-0.354
	(0.258)	(0.273)
Ln. Area	1.025***	1.004***
	(0.0759)	(0.0884)
Ln. 1+Exports in t	0.0113	0.130**
	(0.00683)	(0.0595)
Observations	6,433	6,433
R-squared	0.730	0.263
F.E. Year	Yes	Yes
F.E. Provincia	Yes	Yes
Clust. per Provincia	Yes	Yes
Region	Full	Full

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses.

9. References

Antweiler, W., Copeland, B. R., & Taylor, M. S. (2001). Is free trade good for the environment? American Economic Review, 91(4), 877-908.

Autor, D. H., Dorn, D., & Hanson, G. H. (2015). Untangling trade and technology: Evidence from local labour markets. The Economic Journal, 125(584), 621-646.

Balboni, C., Berman, A., Burgess, R., & Olken, B. A. (2023). The economics of tropical deforestation. Annual Review of Economics, 15, 723-754.

Borda-Niño, M., Meli, P., & Brancalion, P. H. (2020). Drivers of tropical forest cover increase: A systematic review. Land Degradation & Development, 31(11), 1366-1379.

Bombardini, M., & Li, A. (2020). Trade, pollution, and mortality in China. Journal of International Economics, 125, 103309.

Borusyak, K., Hull, P., & Jaravel, X. (2022). Quasi-experimental shift-share research designs. The Review of economic studies, 89(1), 181-213.

Borusyak, K., Hull, P., & Jaravel, X. (2024). A practical guide to shift-share instruments (No. w33236). National Bureau of Economic Research.

Carreira, I., Costa, F., & Pessoa, J. P. (2024). The deforestation effects of trade and agricultural productivity in Brazil. Journal of Development Economics, 167, 103217.

Copeland, B. R., & Taylor, M. S. (2003). Trade and the environment: Theory and evidence. Princeton University Press.

Dasgupta, S. P. (2021). The economics of biodiversity the Dasgupta review abridged version.

Du, X., Li, Y., & Zou, H. (2024). Trade, trees, and lives. NBER Working Paper No. 33143.

Frankel, J. A., & Rose, A. K. (2005). Is trade good or bad for the environment? Sorting out the causality. Review of Economics and Statistics, 87(1), 85-91.

Franklin Jr, S. L., & Pindyck, R. S. (2018). Tropical forests, tipping points, and the social cost of deforestation. Ecological Economics, 153, 161-171.

Goldsmith-Pinkham, P., Sorkin, I., & Swift, H. (2020). Bartik instruments: What, when, why, and how. American Economic Review, 110(8), 2586-2624.

McLaren, A., Saygili, M., & Shirotori, M. (2018). Revealed factor intensity of products: Insights from a new database (No. 81). United Nations Conference on Trade and Development.

Mesquita Moreira, M., Blyde, J., Volpe, C., & Molina, D. (2013). Too Far to Export: Domestic transport costs and regional export disparities in Latin America and the Caribbean.

Pierce, J. R., & Schott, P. K. (2020). Trade liberalization and mortality: Evidence from US counties. American Economic Review: Insights, 2(1), 47-64.

Seminario, B., & Palomino, L. (2022). Estimación del PIB a nivel subnacional utilizando datos satelitales de luminosidad: Perú, 1993-2018. Universidad del Pacífico.

Shirotori, M., Tumurchudur, B., & Cadot, O. (2010). Revealed factor intensity indices at the product level (Vol. 44). UN.

Grosset, F., Papp, A., & Taylor, C. (2023). Rain follows the forest: Land use policy, climate change, and adaptation. Climate Change, and Adaptation (December 1, 2023).