

Institutional complementarity and the export effects of forest certification in global wood markets

Inoussa Boubacar  and Zhen Cai

USDA Forest Product Laboratory, 1 Gifford Pinchot Drive, Madison, WI 53726, USA

Corresponding author: Inoussa Boubacar (email: Inoussa.boubacar@usda.gov)

Abstract

The growing adoption of forest certification reflects a global shift toward more sustainable forest management and trade. Yet, the trade impacts of certification remain uneven, shaped by how these voluntary standards interact with national legal and regulatory environments. This study explores the conditions under which forest certification influences wood product exports, with a particular attention to the concept of institutional complementarity, where private standards and public laws reinforce each other. Using an extended gravity model of bilateral trade, the analysis integrates certification data with indicators of forest laws and legality-focused trade regulations. The results suggest that certification is more likely to support export performance when implemented within countries that possess coherent legal frameworks and effective enforcement mechanisms. In contrast, weak institutional alignment may reduce the benefits of certification or even hinder trade. These findings highlight the importance of regulatory coherence in realizing the trade potential of sustainability initiatives and point to the need for more context-sensitive approaches that consider the institutional realities of both exporting and importing countries.

Key words: forest certification, sustainable trade, timber exports, non-tariff barriers, institutional complementarity

Introduction

The global forest products sector plays a significant role in international trade, supplying timber and wood-based commodities that support economic development and livelihoods in both industrialized and developing regions. Certified wood products have become particularly significant for exporters aiming to access high-value markets that require credible assurance of legal and sustainable sourcing. Since the early 1990s, the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) have become the two most widely recognized certification systems in forestry. Both seek to promote sustainable forest management by applying environmental, social, and economic standards, but they differ in governance structure and approach to standard-setting (Auld et al. 2008; Brashaw and Bergman 2021; Boubacar and Sissoko 2025).

These certification systems have expanded globally over the past three decades, reflecting a broader shift toward market-based environmental governance (Ehrenberg-Azcárate and Peña-Claros 2020; Boubacar and Sissoko 2025). Certified wood products are often positioned as a pathway to high-value markets in which buyers expect verifiable evidence of sustainable sourcing. In these markets, certified producers may benefit from price premiums, improved access, and enhanced reputational value (Auld et al. 2008). However, the heterogeneous trade-enhancing effects of certification are observed across countries and regions. In some contexts, certification may facilitate market access by improving credibil-

ity and reducing information asymmetries; in others, it can act as a nontariff barrier that raises costs without delivering measurable export gains (Guan and Sheong 2019). Illustratively, Klarić et al. (2023) reported that certified Croatian wood products achieved greater competitiveness and higher prices in European markets, while Zhang et al. (2022) observed volume gains for selected certified product categories in China. In contrast, other research has identified negligible or even adverse effects, especially when compliance costs are high or when exporters operate in markets with weak institutional support (Chen et al. 2020). Broadly, the existing literature attributes the divergent export outcomes across countries to differences in institutional capacity, including regulatory coherence, enforcement strength, and access to certification infrastructure (Purwanto et al. 2019; Xu and Lu 2021).

A possible missing link that may help explain the observed variation is the concept of institutional complementarity, the extent to which private certification systems and public regulatory frameworks reinforce one another. Prior studies suggest that certification is more likely to be effective when it complements legality requirements rather than duplicating them (Ebeling and Yasue 2009; Overdevest and Zeitlin 2014). Still, other scholars caution that inconsistencies in the interpretation and enforcement of certification standards at the national level (Lewin et al. 2019; Purwanto et al. 2019), and skepticism over the credibility of certification systems in high-standard markets (Auriol and Schilizzi 2015), can undermine the effectiveness of certification. These challenges

point to the importance of tailoring certification to national contexts and fostering institutional coordination to reduce friction between overlapping policy instruments.

Despite the growth of FSC and PEFC adoption, important questions remain about how these systems interact with diverse legal and institutional settings to shape export outcomes. First, most empirical studies combine certification systems into a single measure, making it difficult to distinguish potential differences in their effects. Second, relatively few studies explicitly incorporate legality-based trade policies, such as forest laws or import bans on illegal timber, into models of certification's market impacts. Third, the role of institutional complementarity between certification and public regulation in influencing export performance has received limited attention, even though such alignment likely influences market access and competitiveness. These dynamics are particularly salient for countries in the Global South, which possess some of the world's most extensive and ecologically important forest resources yet often struggle with limited enforcement capacity, high certification costs, and uneven access to technical expertise (Kaplinsky 2010; Holopainen et al. 2015). For those countries, certification can be both an opportunity to align with global sustainability norms and a potential source of exclusion from premium

markets if institutional and financial constraints are not addressed. This gap limits our understanding of how certification functions within diverse regulatory environments. To address this, the present study contributes to the existing literature by empirically examining how FSC and PEFC influence wood product export performance under varying legal and institutional settings. Using an augmented gravity model of bilateral exports, the analysis integrates certification indicators with measures of legality-focused trade policies and evaluates their interactions effects on export outcomes.

Methodology

To empirically assess the relationship between forest certification and wood product exports, we build on the traditional gravity model of trade. This model, widely used in international trade literature (Anderson 1979), is well-suited for analyzing bilateral trade flows and examining the influence of structural, economic, and institutional determinants. Here, the model has been adapted to include not only standard trade variables but also key institutional factors—namely, the use of forest certification and the presence of trade-related forest laws. The baseline equation is modelled as follows:

$$(1) \quad \ln(\text{Exports}_{ijt}) = \beta_0 + \beta_1 (\text{Certification}_{it}) + \beta_2 \ln(\text{Distance}_{ij}) + \beta_3 \ln(\text{Population}_{it}) + \beta_4 \ln(\text{Population}_{jt}) \\ + \beta_5 \ln(\text{Tariff}_{ijt}) + \beta_6 (\text{Wood Trade Policy}_t) + \beta_7 \ln(\text{REER}_{it}) + \beta_8 \ln(\text{GDP}_{it}) \\ + \beta_9 \ln(\text{GDP}_{jt}) + \beta_{10} \ln(\text{Forest Area}_{it}) + \beta_{11} \ln(\text{MVA}_{it}) + \beta_{12} (\text{LDC}_{jt}) + \alpha_i + \gamma_t + \varepsilon_{it}$$

where $\ln(\text{Exports}_{ijt})$ is the natural logarithm of the volume of wood products exports from country i to country j at time t . This paper focuses on softwood lumber exports, as they represent one of the most important traded wood products (Boubacar 2024). $\text{Certification}_{it}$ denotes the percentage of certified forest area relative to total forest area in country i at time t , measured separately for FSC and PEFC. It is expected that a higher percentage of certified forests will positively influence export volumes due to better market access and potentially higher demand for certified wood products. Although FSC and PEFC may coexist within the same country, the model estimates the marginal association between the area certified under each standard and export volumes at the bilateral level. These effects reflect variation in certification coverage, conditional on country level and bilateral covariates, without implying mutual exclusivity or a direct comparative evaluation. $\ln(\text{Distance}_{ij})$ captures the natural logarithm of the geographical distance between country i and country j . This variable is included to account for transportation costs, which typically negatively influence trade flows. $\ln(\text{Population}_{it})$ and $\ln(\text{Population}_{jt})$ represent the natural logarithm of total population in the exporting country and importing country, respectively. The population variable serves as a proxy for market size and labor supply, which influence production capacity for exports. This is consistent with foundational work by Isard (1954) and later develop-

ments by Anderson and van Wincoop (2003) that link demographic gravitation to trade flows. $\ln(\text{Tariff}_{ijt})$ indicates the natural logarithm of the tariff rate imposed by country j on wood products from country i . This variable affects trade by making imports more expensive and potentially reducing the volume of exports. $\ln(\text{REER}_{it})$ is the natural logarithm of the real effective exchange rate (REER) of country j at time t , capturing the competitiveness of exports. A higher REER indicates that the country's goods are more expensive for foreign buyers, potentially reducing export volumes. $\ln(\text{GDP}_{jt})$ and $\ln(\text{GDP}_{it})$ are the natural logarithm of the gross domestic product (GDP) of the importing country j at time t and exporting country i at time t , respectively. GDP serves as a measure of economic mass, reflecting a country's capacity to produce and consume goods, which directly affects trade volumes; this is supported by Anderson (2011) and Herman and Oliver (2023), who emphasize GDP's central role in the theoretical and empirical success of gravity-based trade estimation.

$\ln(\text{Forest Area}_{it})$ denotes the natural logarithm of the total forest area in country i at time t . It represents the availability of raw materials for exports, which may influence the volume of wood products available for trade. $\ln(\text{MVA}_{it})$ is the natural logarithm of manufacturing value added (MVA) in country i at time t . This variable captures the level of industrialization and processing capacity within the exporting

country, which may enhance the ability to produce and export wood products. To account for structural differences in trade dynamics, we include a dummy variable identifying whether the importing country is classified as a least developed country (LDC) according to United Nations criteria. This variable captures such constraints as limited infrastructure, low productive capacity, and institutional weaknesses, that systematically affect trade performance and are not reflected in standard economic indicators like GDP or population. Moreover, LDCs often benefit from preferential trade agreements and special treatment under international trade regimes, which can significantly influence export outcomes; thus, controlling for LDC status helps isolate these effects (Klasen et al. 2021). Wood Trade Policy is a binary variable that accounts for various aspects of regulatory frameworks that have the potential to shape the volume of bilateral trade. For example, the 2008 Lacey Act Amendment, the 2013 European Union Timber Regulation, the 2016 Indonesia's Import Control System, the European Union Forest Law Enforcement Governance and Trade, the 2012 Australia's Illegal Logging Prohibition Act, the 2017 Malaysia's Timber Legality Assurance System, the 2017 Japan's Import Provisions Under the Clean Wood Act, are all accounted for using the proxy variable Wood Trade Policy measured as either "illegal timber ban" or "forest law".

α_i is the country-fixed effects, capturing time-invariant characteristics of the exporting country i .

γ_t is the time fixed effects, capturing global trends or shocks that affect all countries equally in time t . ε_{it} represents

the error term, capturing unobserved factors that influence the export volume, and is assumed to be uncorrelated with the explanatory variables. And β_s ($s = 1, \dots, 12$) are coefficients to be estimated.

Undoubtedly export prices are important determinants of trade flows; however, consistent bilateral price data for forest products are not readily available across countries and over time. As a result, the price effects are not directly modeled in the analysis. To account for price-related influences indirectly, the model includes import tariffs and REERs, which affect relative prices and export competitiveness. Specifically, tariffs reflect policy-based distortions in trade prices, while exchange rates capture currency-induced shifts in export pricing. GDP and total population are retained as broader proxies for economic size and market development, though these variables may also partially reflect underlying price levels. These conventional economic and geographic variables are incorporated alongside certification and governance indicators in the baseline gravity specification.

In the second phase of the analysis, to explore whether the impact of certification depends on broader policy conditions, we extend the baseline model by adding interaction terms. These interactions combine certification with three types of forest-related policy variables: forest laws in the importing country, forest laws in the exporting country, and bans on illegal timber trade.

The extended interaction model is specified as follows:

$$(2) \quad \ln(Exports_{it}) = \beta_0 + \beta_1(\text{Certification}_{it}) + \beta_2 \ln(\text{Distance}_{ij}) + \beta_3 \ln(\text{Population}_{it}) + \beta_4 \ln(\text{Population}_{jt}) + \beta_5 \ln(\text{Tariff}_{ijt}) \\ + \beta_6(\text{Wood Trade Policy}_t) + \beta_7(\text{Wood Trade Policy}_t \times \text{Certification}_{it}) + \beta_8 \ln(\text{REER}_{it}) \\ + \beta_9 \ln(\text{GDP}_{it}) + \beta_{10} \ln(\text{GDP}_{jt}) + \beta_{11} \ln(\text{Forest Area}_{it}) + \beta_{12} \ln(\text{MVA}_{it}) + \beta_{13}(\text{LDC}_{jt}) + \alpha_i + \gamma_t + \varepsilon_{it}$$

A key innovation of this model is the inclusion of interaction terms between certification variables and legality-based trade policies to test for institutional complementarity. This formulation enhances the analytical relevance of the analysis as it allows for the identification of conditional effects: specifically, whether certification leads to different trade outcomes depending on the existence and type of forest-related regulation in the trade relationship.

The data for this study come from well-established international databases. Export volumes are taken from FAO-STAT (FAO 2025) and UN COMTRADE. Information on certification levels is sourced directly from FSC (FSC 2025) and PEFC (PEFC 2025). Macroeconomic indicators like GDP, population, and real exchange rates come from the World Bank's World Development Indicators (World Bank 2025), while tariff data are drawn from the World Integrated Trade Solution. Distance between countries is calculated using the CEPII GeoDist database (CEPII 2025). Forest policy variables were compiled from national legal documents, international trade agreements, and forest governance assessments. The panel includes bilateral export data on 24 exporting countries and 82 importing countries, resulting in 12 312

unique country pairs. Export flows are modeled from each country of origin to each destination market where trade occurred and for which data on forest certification were available.

Table 1 provides a summary of all the key variables and their sources.

Results

This section presents the empirical findings from the extended gravity model, focusing on the effects of forest certification and trade policies on global wood product exports. Results are derived from several model specifications and robustness checks to isolate the impacts of PEFC and FSC certification, both independently and in interaction with legality-based trade policies. The results, summarized in Tables 2–5, reveal nuanced and, in some cases, unexpected relationships between forest certification systems and wood product export volumes, offering new insights into how certification affects trade dynamics across diverse global contexts.

Table 1. Variables used in augmented gravity models of bilateral softwood lumber trade.

Variable	Description	Source
Exports	Volume of wood products exports (m ³)	FAOSTAT, United Nations COMTRADE
Certification (FSC/PEFC)	Certified forest area as a % of total forest	FSC, PEFC
Distance	Bilateral distance between trading partners	CEPII GeoDist Database
Population	Total population	World Bank
Tariff	Tariff rate imposed by importing country (%)	World Integrated Trade Solution (WITS)
Wood Trade Policy	Dummy for legality-focused import/export restrictions	Compiled from national policies, The International Tropical Timber Organization, European Commission
REER	Real effective exchange rate	World Bank
GDP _{it}	GDP of exporting country (constant 2015 USD)	World Bank
GDP _{jt}	GDP of importing country (constant 2015 USD)	World Bank
Forest area	Total forest area of exporting country	FAOSTAT
MVA	Manufacturing value added in exporting country	World Bank

Note: This table summarizes the dependent and independent variables, their measurement units, and data sources used in the panel dataset (24 exporting countries × 82 importing countries; 12 312 country pairs). Acronyms: FSC = Forest Stewardship Council; PEFC = Programme for the Endorsement of Forest Certification; REER = real effective exchange rate; GDP = gross domestic product; MVA = manufacturing value added; LDC = least developed country. Export volumes are measured in cubic meters (m³); forest certification is expressed as the share of national forest area certified (%); tariffs are ad valorem rates (%).

Table 2. Baseline gravity model: association between forest certification and bilateral softwood lumber export volumes.

Variable	Model 1	Model 2	Model 3
PEFC	0.0018*** (0.0008)	0.0188*** (0.0008)	0.0176*** (0.0009)
FSC certification	0.0043*** (0.0014)	0.0049*** (0.0014)	0.0047*** (0.0014)
Distance	−1.075*** (0.03)	−1.088*** (0.03)	−1.049*** (0.029)
Population in exporting country	0.0094 (0.048)	0.026 (0.048)	−0.11 (0.052)
Population in importing country	0.692*** (0.016)	0.691*** (0.016)	0.671*** (0.016)
Tariffs	0.391*** (0.038)	0.337*** (0.039)	0.446*** (0.038)
Forest law in importing country	−0.334*** (0.055)		
Illegal timber ban in importing country		−0.466*** (0.057)	
Forest law in exporting country			0.634*** (0.119)
Exchange rate	0.335*** (0.015)	0.336*** (0.015)	0.280*** (0.018)
GDP in exporting country	−0.409*** (0.040)	−0.419*** (0.040)	−0.308*** (0.045)
GDP in importing country	0.027*** (0.0055)	0.026*** (0.0054)	0.022*** (0.0054)
Forest area exporting country	0.824*** (0.021)	0.827*** (0.021)	0.809*** (0.021)
MVA in exporting country	−0.636*** (0.064)	−0.653*** (0.064)	−0.682*** (0.065)
If least developed importing country = 1	−1.563*** (0.071)	−1.604*** (0.071)	−1.519*** (0.069)
Intercept	5.342*** (0.554)	5.535*** (0.553)	4.894*** (0.566)

Note: The dependent variable is the natural logarithm of bilateral export volume (m³). Key regressors include forest certification shares for PEFC (Programme for the Endorsement of Forest Certification) and FSC (Forest Stewardship Council), geographic distance, tariffs (%), population, real effective exchange rate (REER), gross domestic product (GDP), forest area, manufacturing value added (MVA), and an indicator for least developed country (LDC) importers. Country and year fixed effects are included. “Wood Trade Policy” is proxied differently across specifications: Model 1 uses forest law (importing country), Model 2 uses an illegal timber ban (importing country), and Model 3 uses forest law (exporting country). Coefficients are log-linear estimates; robust standard errors are reported in parentheses; *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Table 3. Gravity model estimates with PEFC only: bilateral softwood lumber export volumes.

Variable	Model 1	Model 2	Model 3
PEFC	0.018*** (0.001)	0.018*** (0.001)	0.017*** (0.001)
Distance	−1.08*** (0.03)	−1.093*** (0.03)	−1.054*** (0.029)
Population in exporting country	0.0014 (0.048)	0.018 (0.048)	−0.105* (0.052)
Population in importing country	0.692*** (0.016)	0.692*** (0.016)	0.672*** (0.015)
Tariffs	0.388*** (0.038)	0.336*** (0.039)	0.437*** (0.038)
Forest law in importing country	−0.319*** (0.055)		
Illegal timber ban in importing country		−0.443*** (0.057)	
Forest law in exporting country			0.565*** (0.117)
Exchange rate	0.336*** (0.015)	0.338*** (0.015)	0.287*** (0.018)
GDP in exporting country	−0.426*** (0.0399)	−0.437*** (0.039)	−0.336*** (0.044)
GDP in importing country	0.027*** (0.0055)	0.026*** (0.0054)	0.022*** (0.005)
Forest area exporting country	0.834*** (0.021)	0.839*** (0.021)	0.821*** (0.021)
MVA in exporting country	−0.691*** (0.062)	−0.715*** (0.062)	−0.737*** (0.063)
If least developed importing country = 1	−1.566*** (0.071)	−1.605*** (0.071)	−1.523*** (0.069)
Intercept	5.963*** (0.515)	6.239*** (0.515)	5.635*** (0.521)

Note: The dependent variable is the natural logarithm of bilateral export volume (m^3). This specification mirrors Table 2 but includes only the certification share for PEFC (Programme for the Endorsement of Forest Certification), omitting FSC. The same set of controls is applied: geographic distance, tariffs (%), population, real effective exchange rate (REER), gross domestic product (GDP), forest area, manufacturing value added (MVA), and an indicator for least developed country (LDC) importers. Country and year fixed effects are included. “Wood Trade Policy” is proxied as follows: Model 1 uses forest law (importing country), Model 2 uses an illegal timber ban (importing country), and Model 3 uses forest law (exporting country). Coefficients are log-linear estimates; robust standard errors are reported in parentheses; *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Baseline model

Table 2 shows results from the baseline gravity model, which incorporates both PEFC and FSC certification alongside standard trade determinants and structural control variables. The “Forest Law in importing country” (in Model 1 Table 2), “Illegal Timber Ban in importing country” (in Model 2 Table 2), and “Forest Law in exporting country” (in Model 3 Table 2) are proxy variables for “Wood Trade Policy”. This specification provides the empirical foundation for assessing the general relationship between certification and export performance across all countries and time periods.

Table 2 indicates a consistent and statistically significant association between the proportion of a country’s forest area certified and the volume of its wood product exports. Across all three model specifications, the estimated coefficients for PEFC are positive and significant at the 1% level, ranging from 0.0018 in Model 1 to 0.0188 in Model 2 and 0.0176 in Model 3. Similarly, the estimated coefficients for FSC certification are positive and significant at the 1% level, with values of 0.0043, 0.0049, and 0.0047 in Models 1, 2, and 3, respectively. Within the context of the sample and model specification, these re-

sults imply that greater coverage of certified forest area is therefore associated with higher export volumes, holding all other factors constant.

The control variables behave largely as expected in the gravity model framework. Bilateral distance is negative and highly significant with estimated coefficients ranging from −1.088 to −1.049, reflecting transportation costs and logistical constraints (Anderson 1979). Consistent with the expectations of the gravity model, population in importing countries is positively and statistically associated with export volume, with coefficients estimated at 0.692, 0.691, and 0.671 in Models 1, 2, and 3, respectively. However, in exporting countries, population size is not statistically significant when other factors are held constant. Legality-related variables are statistically significant, with directions consistent with international trade agreement policies. Specifically, both forest law and illegal timber ban in importing countries are negatively correlated with export volumes, whereas forest law in exporting countries shows a positive estimated coefficient. Macroeconomic and structural controls, such as exchange rates, GDP, MVA, and forest area as a proxy for

Table 4. Gravity model estimates with FSC certification only: bilateral softwood lumber export volumes.

Variable	Model 1	Model 2	Model 3
FSC certification	−0.0028** (0.002)	−0.0025* (0.001)	−0.001 (0.001)
Distance	−1.075*** (0.030)	−1.081*** (0.030)	−1.067*** (0.029)
Population in exporting country	−0.395*** (0.044)	−0.389*** (0.045)	−0.507*** (0.049)
Population in importing country	0.677*** (0.016)	0.677*** (0.016)	0.666*** (0.015)
Tariffs	0.320*** (0.038)	0.290*** (0.039)	0.369*** (0.038)
Forest law in importing country	−0.214*** (0.056)		
Illegal timber ban in importing country		−0.267*** (0.057)	
Forest law in exporting country			0.661*** (0.121)
Exchange rate	0.311*** (0.015)	0.313*** (0.015)	0.255*** (0.018)
GDP in exporting country	−0.133*** (0.038)	−0.137*** (0.038)	−0.034 (0.043)
GDP in importing country	0.026*** (0.005)	0.025*** (0.006)	0.023*** (0.005)
Forest area exporting country	0.799*** (0.021)	0.802*** (0.021)	0.788*** (0.021)
MVA in exporting country	−0.755*** (0.065)	−0.767*** (0.066)	−0.804*** (0.066)
If least developed importing country = 1	−1.455*** (0.071)	−1.47*** (0.072)	−1.442*** (0.071)
Intercept	6.077*** (0.563)	6.199*** (0.562)	5.523*** (0.574)

Note: The dependent variable is the natural logarithm of bilateral export volume (m^3). This specification mirrors Table 2 but includes only the certification share for FSC (Forest Stewardship Council), omitting PEFC. The same set of controls is applied: geographic distance, tariffs (%), population, real effective exchange rate (REER), gross domestic product (GDP), forest area, manufacturing value added (MVA), and an indicator for least developed country (LDC) importers. Country and year fixed effects are included. “Wood Trade Policy” is proxied as follows: Model 1 uses forest law (importing country), Model 2 uses an illegal timber ban (importing country), and Model 3 uses forest law (exporting country). Coefficients are log-linear estimates; robust standard errors are reported in parentheses; *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

resource endowment, also exhibit the expected signs and significance patterns. Notably, importers classified as LDCs consistently display negative and statistically significant coefficients across all three specifications.

Drawing on these results, the subsequent specifications analyze each certification system separately to clarify their distinct relationships with trade flows.

Isolated effect of PEFC

When the model includes only PEFC variable, its estimated effect remains positive, statistically significant, and stable across all three specifications. The coefficients, approximately 0.018, suggest a modest yet meaningful trade-enhancing impact. Specifically, a 10% increase in PEFC-certified forest area is associated with approximately 0.18% increase in bilateral wood product export volume, holding other factors constant. This magnitude is in line with findings from Chen et al. (2020), who reported modest but positive effects of certification on trade, especially in middle-income countries where compliance burdens were manageable.

The control variables continue to follow patterns consistent with the baseline specification. For instance, distance remains strongly negative, population in importing countries is positive and significant, and legality-focused policies maintain their expected signs and significance. Exchange rates, GDP, MVA, and forest area behave as expected; tariffs remain positive; and the least-developed importer dummy consistently shows negative effects.

The results suggest a consistent positive relationship between PEFC and export performance, setting the stage for assessing the isolated effect of FSC certification.

Isolated effect of FSC certification

Table 4 presents estimation results from a specification in which FSC certification is the sole certification variable included in the model. This specification enables a focused evaluation of how FSC-certified forest area correlates with bilateral wood product exports, without influence from other certification systems or joint adoption effects.

Across all three model variations, the estimated coefficients on FSC certification are consistently negative, ranging

Table 5. Extended gravity model with certification–governance interactions: bilateral softwood lumber export volumes.

Variable	Model 1	Model 2	Model 3
PEFC	0.017*** (0.001)	0.017*** (0.001)	0.018*** (0.001)
FSC certification	−0.001 (0.002)	0.003* (0.002)	0.006*** (0.001)
Distance	−1.059*** (0.030)	−1.078*** (0.029)	−1.045*** (0.028)
Population in exporting country	0.002 (0.048)	0.024 (0.048)	−0.128** (0.052)
Population in importing country	0.690*** (0.016)	0.691*** (0.015)	0.669*** (0.015)
Tariffs	0.383*** (0.037)	0.334*** (0.038)	0.453*** (0.038)
Forest law in importing country	−0.657*** (0.089)		
Illegal timber ban in importing country		−0.646*** (0.088)	
Forest law in exporting country			−0.027 (0.149)
PEFC × forest law in importing country	0.004*** (0.001)		
FSC × forest law in importing country	0.012*** (0.002)		
PEFC × illegal timber ban in importing country		0.004** (0.001)	
FSC × illegal timber ban in importing country		0.003 (0.002)	
PEFC × forest law in exporting country			−0.0039 (0.012)
FSC × forest law in exporting country			0.177*** (0.021)
Exchange rate	0.327*** (0.015)	0.331*** (0.015)	0.246*** (0.018)
GDP in exporting country	−0.404*** (0.077)	−0.419*** (0.040)	−0.279*** (0.044)
GDP in importing country	0.027*** (0.005)	0.026*** (0.005)	0.020*** (0.005)
Forest area exporting country	0.821*** (0.021)	0.824*** (0.021)	0.796*** (0.021)
MVA in exporting country	−0.651*** (0.064)	−0.656*** (0.064)	−0.471*** (0.070)
If least developed importing country = 1	−1.565*** (0.071)	−1.60*** (0.071)	−1.531*** (0.069)
Intercept	5.463*** (0.554)	5.568*** (0.553)	4.435*** (0.567)

Note: The dependent variable is the natural logarithm of bilateral export volume (m^3). Main effects include certification shares for PEFC (Programme for the Endorsement of Forest Certification) and FSC (Forest Stewardship Council), along with standard gravity controls: geographic distance, tariffs (%), population, real effective exchange rate (REER), gross domestic product (GDP), forest area, manufacturing value added (MVA), and an indicator for least developed country (LDC) importers. Country and year fixed effects are included. Interaction terms capture institutional complementarity between certification and governance: (i) certification × forest law (importing country), (ii) certification × illegal timber ban (importing country), and (iii) certification × forest law (exporting country). Coefficients are log-linear estimates; robust standard errors are reported in parentheses; *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

from −0.0028 to −0.001, though with reduced statistical and economic significance. These estimates imply that a 10% increase in FSC-certified forest area corresponds to roughly a 0.28%–0.01% decline in wood product export volume, holding other factors constant.

The standard gravity control variables continue to align with prior patterns, showing no notable changes in their eco-

nomics or statistical significance. However, the coefficients for the population of exporting countries are now negative and statistically significant at the 1% level across all three specifications, with values ranging from −0.507 to −0.389. Likewise, trade-legality measures maintain their expected signs and significance, consistent with the results reported in Tables 2 and 3.

The final set of models expands the baseline export equation to include (certification $\times$ wood trade policy) interaction terms, further exploring the conditional effects of sustainability mechanisms on export performance. This addition is theoretically justified by the understanding that environmental policy instruments and market-based certification systems often operate within overlapping institutional frameworks, potentially reinforcing or undermining each other's effectiveness (Lewin et al. 2019; Xu and Lu 2021).

Extended model with interaction terms

Trade policy theory suggests that nontariff measures, such as legality verification and import restrictions, can modify market incentives for certification by either enhancing access to regulated markets or introducing additional compliance burdens (Cole et al. 2021). The interaction term allows for a more nuanced analysis of whether certification's trade effects vary depending on the presence of legal enforcement frameworks. Thus, the extended model tests for these effects, and the results are summarized in Table 5 and Fig. 1.

Across all three specifications, the estimated effects of certification remain robust, statistically significant, and directionally aligned with the baseline results reported in Table 2. Both certification systems exhibit a positive and economically influence on export volumes, with coefficients ranging from 0.017 to 0.018 for PEFC and from 0.003 to 0.006 for FSC. These findings suggest that certification not only correlates with higher export performance but does so consistently across alternative model specifications, reinforcing the credibility of the baseline estimates.

The interaction terms reveal important context-dependent dynamics, whereas several interactions highlight the role of institutional complementarity. PEFC interacts positively with forest laws in importing countries (0.004) and with illegal timber bans in importing countries (0.004). Similarly, FSC certification shows a positive and significant interaction with forest laws in importing countries (0.012) and a notably large, positive interaction with forest laws in exporting countries (0.177). By contrast, both the interaction between PEFC and forest laws in exporting countries as well as the interaction of FSC and illegal timber bans in importing countries are not statistically significant.

Figure 1 synthesizes the results reported in Table 5, illustrating how the interaction between certification and governance variables shapes export volumes. The figure highlights that the impact of certification is conditional, varying according to the strength of forest laws and the presence of legality restrictions in trade partners.

Furthermore, the main effects for legality policies remain negative and significant, indicating potentially trade-restrictive impacts of such measures absent complementary mechanisms. These results echo findings from Apeti and N'Doua (2023), who argue that the imposition of legality requirements often reduces trade volume, particularly when not accompanied by institutional or technical support. Such regulations, while normatively important, may impose a regulatory burden that constrains exporters with limited com-

pliance capacity. Finally, the control variables maintain their expected signs and significance, with no substantial departures from earlier patterns.

Discussions

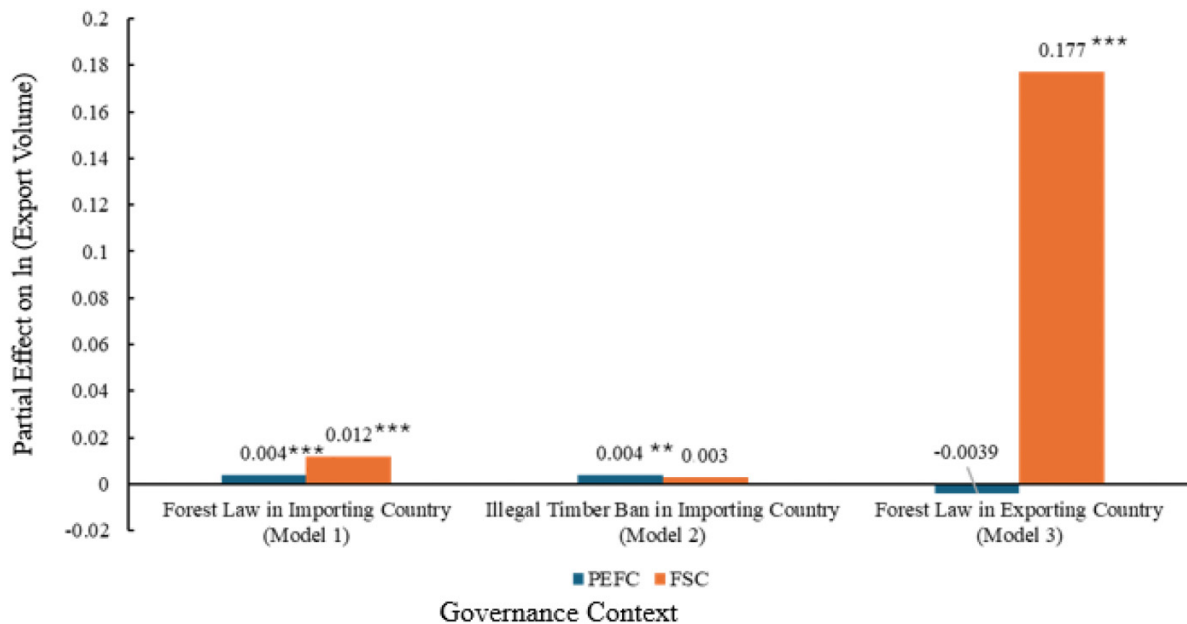
The results from the baseline models indicate that forest certification exerts statistically significant, though varying, effects on wood product export volumes, shaped by broader policy and governance contexts. The consistently positive and significant coefficients for PEFC suggest that, across the sampled countries, this system aligns well with prevailing institutional and market conditions. This finding is consistent with prior empirical evidence from Purwanto et al. (2019), who observed that PEFC contributed positively to export performance by enhancing buyer confidence and reducing transaction costs, thereby lowering barriers for producers seeking certification.

In contrast, the relationship between FSC certification and export volumes appears more nuanced, depending on whether both FSC and PEF are included in the model or modeled separately. When both systems are included, the estimated coefficients for the FSC-certified area are positive and statistically significant, indicating a favorable contribution to export volumes. However, when FSC is the sole certification system, its coefficients are negative, albeit with weak economic and statistical significance, suggesting a potential reduction in export volumes.

This pattern does not necessarily imply that FSC diminishes trade potential; rather, it may reflect the system's more demanding environmental and social requirements, higher compliance costs, and stronger orientation toward niche markets (Boubacar and Sissoko 2025). These factors can limit adoption among exporters serving price-sensitive or less sustainability-driven markets (Tikina and Innes 2008; Hackett 2013). Taken together, these findings highlight the differentiated roles of certification systems within global forest governance, suggesting that PEFC may complement mainstream trade objectives while FSC's design aligns more closely with sustainability norms and niche market strategies. From a practical perspective, this lends support to the need for harmonized certification frameworks or targeted incentives to balance trade competitiveness with environmental integrity, while theoretically reinforcing institutional perspectives on how governance regimes shape market outcomes.

The interaction models provide additional insight into how certification outcomes vary with governance conditions. The first set of findings relates to forest laws in importing countries. The interaction between PEFC and these laws is positive and statistically significant, indicating that PEFC-certified products achieve higher export volumes in markets with established legality verification frameworks. This likely reflects PEFC's alignment with national standards, which facilitates integration into jurisdictions that enforce legality through public regulation. In such contexts, certification can complement enforcement, reduce duplication, and strengthen importer confidence (Lewin et al. 2019; Purwanto et al. 2019).

Fig. 1. Estimated impacts of certification–governance interactions on bilateral softwood lumber export volumes. Note: Panels report partial effects from the extended gravity model relating FSC (Forest Stewardship Council) and PEFC (Programme for the Endorsement of Forest Certification) to bilateral export volumes under three governance conditions: (a) forest laws in importing countries, (b) bans on illegal timber in importing countries, and (c) forest laws in exporting countries. Effects are expressed for the natural logarithm of export volume (m^3); asterisks indicate statistical significance (*, ** at 5% and 1% levels, respectively).



The interaction between FSC certification and importing-country forest laws is also positive and significant. This suggests that FSC delivers measurable trade benefits where legality regulations are strong. Previous studies note that when certification standards lack formal recognition within national legality systems, their complementarity is limited (Auriol and Schilizzi 2015; Holopainen et al. 2015).

The second set of results concerns import restrictions on illegal timber, including bans and due diligence requirements such as the EU Timber Regulation and the U.S. Lacey Act. Here, the interaction between PEFC and these restrictions is positive and significant, consistent with the idea that certification helps exporters demonstrate compliance under legality-based trade rules, reducing transaction costs and legal risks (Cole et al. 2021). In contrast, the FSC interaction term is statistically insignificant. While FSC's audit and traceability systems should, in principle, support compliance (Bartley 2014); the data do not show an incremental trade effect attributable to import restrictions. Any observed gains for FSC in regulated markets likely reflect its main effect rather than an additional boost from these policies.

The third interaction focuses on forest laws in exporting countries. The effect for FSC is large and highly significant, implying that FSC-certified products are considerably more competitive when produced in countries with strong forest governance. For example, a 10-percentage-point increase in FSC-certified forest area under such laws corresponds to roughly a 1.8% rise in export volumes. These conditions likely reduce certification costs, improve monitoring, and signal institutional credibility to buyers, rein-

forcing the role of public–private alignment in sustainability governance (Overdevest and Zeitlin 2014). By contrast, the interaction between PEFC and exporting-country forest laws is not significant. This may reflect PEFC's design principle of coherence with national legal systems: where this coherence already exists, stronger laws add little marginal value. The effect is likely context-dependent—PEFC may provide assurance in weak governance settings, but in high-capacity contexts, legality assurance is already embedded (Giessen et al. 2016).

Overall, the results point to a clear pattern: certification does not produce uniform trade outcomes. Its effectiveness depends on institutional fit. Where certification aligns with legality frameworks, whether in importing or exporting countries, it tends to facilitate market access. Where alignment is weak, benefits diminish and may even become negligible. This underscores a broader principle in sustainability governance: performance depends not only on rule design but on the degree of complementarity between public and private institutions.

These findings highlight the need for stronger alignment between legality policies and certification systems. Options include mutual recognition agreements, integration of legality verification into certification protocols, and capacity-building for enforcement agencies to reduce duplication and compliance costs. Such measures can lower transaction costs and enhance legitimacy. Theoretically, the results reinforce institutionalist and regime-complex perspectives, showing that trade outcomes hinge on the interaction of governance regimes rather than on isolated rule systems.

The control variables behave largely as expected, reinforcing confidence in the model estimates. Geographic distance exerts a strong and consistent negative effect across all specifications, reflecting the role of transportation costs and logistical barriers in dampening trade flows. Market size and economic capacity also matter. Importer GDP and population are both positive and highly significant, indicating that wealthier and larger markets import more wood products. On the exporter side, GDP shows a negative association, which likely reflects structural composition: as economies diversify and industrialize, forest products account for a smaller share of exports. Similarly, MVA is negative and significant in most models, suggesting that industrial capacity does not translate into higher certified wood exports. This aligns with sectoral realities, many certified exports remain raw or semi-processed, so aggregate manufacturing indicators may not capture forest-sector intensity (Tikina and Innes 2008; Hackett 2013). By contrast, forest areas exert a strong positive effect, highlighting the role of resource endowment in shaping trade potential. Larger forest bases provide the raw material foundation for export-oriented production, particularly under certification regimes that require traceability and legality assurance.

Policy-related controls also behave predictably. Tariffs, somewhat unexpectedly, are positive and significant. This pattern may reflect preferential trade margins or collinearity with policy targeting rather than pure protection effects, a point that warrants robustness checks using alternative tariff measures. Exchange rates are positive and significant, consistent with currency depreciation improving export competitiveness.

Beyond broader economic indicators and policy variables, country classification effects also emerge in the analysis. Across all model specifications, the binary indicator for LDC importers is consistently negative and statistically significant, implying that exports to LDC markets are substantially lower than to non-LDC destinations. This magnitude translates to roughly a 78% reduction in trade volumes when the importer is an LDC. The result likely reflects limited purchasing power and infrastructure constraints rather than policy preferences, although preferential schemes such as the EU's Everything But Arms initiative may partially offset these barriers (Bureau et al. 2007; Chauffour and Maur 2011). These findings suggest that while certification can facilitate access to regulated markets, structural constraints in LDCs remain a significant trade limiter.

From a practical perspective, these findings indicate that the effectiveness of certification in facilitating trade is closely linked to the strength and coherence of the legal and institutional environment in which it operates. Evidence from this study suggests that when forest laws are well established, enforcement mechanisms function reliably, and certification is formally embedded within legality verification processes, certification systems are better positioned to support market access. Likewise, compatibility between certification standards and both domestic and international regulatory frameworks appears to enhance their capacity to complement existing

governance arrangements and to signal credibility to buyers in regulated markets.

Robustness check

To address potential endogeneity from the self-selection of certification, we re-estimated the extended gravity model using the Hausman–Taylor (HT) instrumental variable estimator for panel data (Hausman and Taylor 1981). This approach is appropriate in settings where some regressors correlate with unobserved country-pair effects and where time-invariant variables must be retained. Unlike fixed effects, which eliminate time-invariant regressors, and random effects, which assume orthogonality between regressors and unit effects, HT constructs instruments internally from exogenous variation, delivering consistent and efficient estimates under structured exogeneity conditions (Baltagi et al. 2003). This makes HT a suitable option for static panel models with potential correlation between regressors and unobserved heterogeneity. The results are presented in Table 6 and Fig. 2.

The results using the HT estimation approach largely confirm the robustness of the main findings as reported in Table 5. PEFC remains positive and statistically significant across all specifications, indicating a stable, export-enhancing association once correlated effects are addressed. In contrast, FSC certification is consistently negative, reversing the mixed or positive estimates observed under fixed effects on Table 5.

Furthermore, the three governance variables accounting for forest law and ban of illegal timber trade are consistently negative and statistically significant, reinforcing the role of institutional frameworks in shaping trade flows. The consistency of these results is also evident in the estimated interaction terms across all three model specifications, revealing that certification effects are strongly conditioned by governance. Specifically, under importing-country forest (Model 1), PEFC's interaction is positive and significant, amplifying its favorable effect while FSC's interaction with the same law is positive but not significant. Under illegal timber ban (Model 2), both PEFC and FSC interactions are positive and significant. In exporting-country forest law contexts (Model 3), FSC's interaction is strongly positive and highly significant, more than compensating for its negative main effect while PEFC's interaction in this case is positive but not significant. These patterns point to a clear conclusion: certification outcomes depend critically on institutional context, with PEFC aligned mostly with importing-country governance and FSC showing strong complementarity with exporting-country forest law. Finally, the results for the traditional gravity variables are broadly consistent with theoretical priors the HT estimations aligning with the findings summarized in Table 5.

Figure 2 synthesizes the results from Table 6, highlighting how the effects of certification on export volumes vary with institutional context. This supports the view that certification outcomes arise not from certification alone, but from its complementarity with legal and institutional frameworks in both exporting and importing countries.

Table 6. Hausman–Taylor panel estimates with certification–governance interactions: bilateral softwood lumber export volumes.

Variable	Model 1	Model 2	Model 3
PEFC	0.002** (0.001)	0.002** (0.001)	0.004*** (0.001)
FSC certification	−0.006 *** (0.002)	−0.009*** (0.002)	−0.007*** (0.002)
Distance	−0.851 (0.709)	−0.907 (0.72)	−0.298 (0.707)
Population in exporting country	−1.495*** (0.331)	−1.473*** (0.335)	−1.469*** (0.333)
Population in importing country	0.538*** (0.183)	0.475** (0.185)	0.424** (0.182)
Tariffs	−0.185*** (0.039)	−0.185*** (0.04)	−0.178*** (0.039)
Forest law in importing country	−0.266*** (0.076)		
Illegal timber ban in importing country		−0.430*** (0.068)	
Forest law in exporting country			−0.321*** (0.112)
PEFC × forest law in importing country	0.005*** (0.001)		
FSC × forest law in importing country	0.002 (0.002)		
PEFC × illegal timber ban in importing country		0.004*** (0.001)	
FSC × illegal timber ban in importing country		0.008*** (0.002)	
PEFC × forest law in exporting country			0.007 (0.008)
FSC × forest law in exporting country			0.101*** (0.013)
Exchange rate	0.076 (0.062)	0.033 (0.063)	−0.074 (0.066)
GDP in exporting country	−0.669*** (0.156)	−0.498*** (0.163)	−0.827*** (0.158)
GDP in importing country	1.628*** (0.073)	1.681*** (0.093)	1.652*** (0.091)
Forest area exporting country	1.582*** (0.385)	1.611*** (0.39)	1.063*** (0.397)
MVA in exporting country	0.009 (0.060)	0.010 (0.060)	0.175*** (0.063)
If least developed importing country = 1	5.551*** (1.578)	5.694*** (1.602)	5.871*** (1.562)
Intercept	−13.273*** (6.683)	−18.352*** (6.792)	−6.526 (6.732)

Note: The dependent variable is the natural logarithm of bilateral export volume (m³). The Hausman–Taylor (HT) estimator is applied to address potential endogeneity while retaining time-invariant regressors. Main effects include certification shares for PEFC (Programme for the Endorsement of Forest Certification) and FSC (Forest Stewardship Council), geographic distance, tariffs (%), population, real effective exchange rate (REER), gross domestic product (GDP), forest area, manufacturing value added (MVA), and an indicator for least developed country (LDC) importers, along with governance proxies (forest law or illegal timber ban). Interaction terms mirror those in Table 5. Coefficients are log-linear estimates; robust standard errors are reported in parentheses; *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

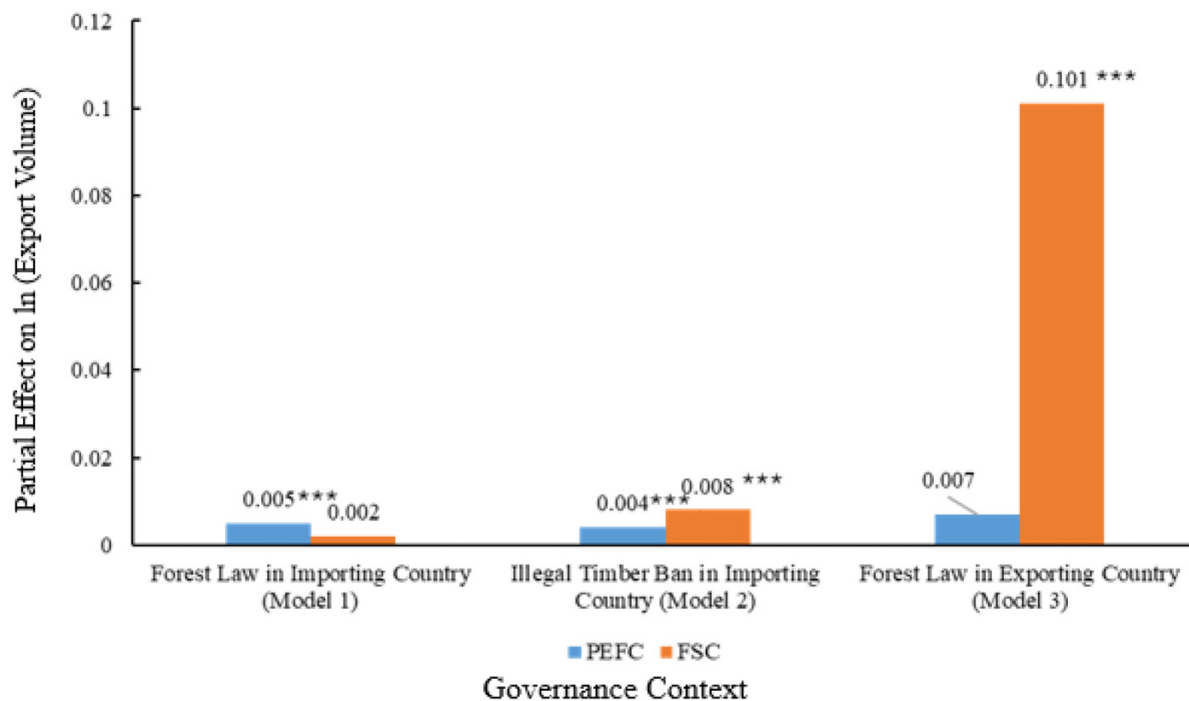
Conclusion

This study examines how forest certification interacts with the legal and institutional settings of both exporting and importing countries to shape patterns in wood products trade. By analyzing these relationships through the lens of institutional complementarity, which holds that public regulations

and private standards can reinforce each other when implemented in coherent policy environments (Hall and Soskice 2001), the research contributes to understanding the conditions under which certification is most closely associated with market outcomes.

The results suggest that certification is not uniformly associated with higher export performance. While the statistical

Fig. 2. Interaction effects under the Hausman–Taylor (HT) estimator for bilateral softwood lumber export volumes. Notes: Panels display estimated partial effects of certification–governance interactions from HT regressions, including: (a) certification $\times$ forest law (importing country), (b) certification $\times$ illegal timber ban (importing country), and (c) certification $\times$ forest law (exporting country). Certification systems include FSC (Forest Stewardship Council) and PEFC (Programme for the Endorsement of Forest Certification). Effects are expressed for the natural logarithm of export volume (m^3); asterisks indicate statistical significance (*, ** at 5% and 1% levels, respectively).



relationships are significant, they should be interpreted as correlations rather than proof of causation. The observed effects appear to depend on the broader legal and institutional context in which certification is implemented. Specifically, certification is more often linked to greater export volumes when it operates in jurisdictions with clear regulations, effective enforcement, and governance systems that support verification and transparency. In contrast, where such alignment is absent, certification may not lead to measurable trade gains and could even correlate with trade declines, likely due to overlapping verification requirements or administrative complexity.

Framing the findings in terms of institutional complementarity positions certification not as an isolated intervention but as part of an interconnected set of governance arrangements. This perspective resonates with scholarship emphasizing that the effectiveness of sustainability initiatives depends on how they interact with existing institutional frameworks, rather than on their design features alone.

Notwithstanding the valuable empirical contributions of this study, a few limitations warrant consideration. First, it relies on national-level certification indicators, which may obscure important intra-country and firm-level dynamics. For instance, differences in firm size, export orientation, or access to certification subsidies could yield variation in certification impacts that the current model does not capture. Second, certification status is treated in quantitative terms,

based on the extent of certified forest area as a proxy, without accounting for variation in the depth or credibility of implementation across jurisdictions. Third, although the varied model specifications used in this study control for a wide range of economic and policy factors, self-selection bias remains a concern. For instance, the decision to adopt certification may not occur randomly; rather, it may reflect systematic differences among countries, especially in their export orientation and expectations regarding future trade opportunities. Although the panel structure helps control for unobserved heterogeneity, it cannot fully account for factors such as shifting buyer preferences or supply chain configurations.

Future research could address the aforementioned boundaries by integrating trade statistics with firm-level or product-level data, allowing for more granular examination of how certification interacts with different supply chains and market segments. Quasi experimental approaches could also shed light on how legality frameworks engage with certification in practice, and the implications for participation and market access in varying regulatory settings. Such work would extend understanding of how institutional complementarity operates across contexts and deepens insights into the pathways through which certification affects trade.

Despite these limitations, the findings point to several areas of potential relevance for practice and research. Certification outcomes appear more favorable when aligned with the institutional capacities of exporting countries and

when supported by coherent legality frameworks in importing markets. Strengthening coordination between voluntary sustainability standards and legality-focused trade policies may help reduce regulatory overlap and improve market access. In countries with limited administrative resources, targeted measures such as technical assistance, financial support, and financial support can help expand participation and enhance export performance. These observations indicate that well-designed, context-sensitive certification frameworks may play a meaningful role in advancing sustainability transitions that are both environmentally credible and economically inclusive.

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Data availability

Data generated or analyzed during this study are available from the corresponding author upon reasonable request.

Author information

Author ORCIDs

Inoussa Boubacar <https://orcid.org/0000-0002-9260-9854>

Author contributions

Conceptualization: IB, ZC

Data curation: IB, ZC

Formal analysis: IB, ZC

Methodology: IB, ZC

Project administration: IB

Software: IB, ZC

Supervision: IB

Validation: ZC

Visualization: IB

Writing – original draft: IB

Writing – review & editing: IB, ZC

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