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Friends or Foes? The Impact of Voluntary Sustainability Standards on Agricultural Exports of Developing Countries

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Integration and Trade Sector

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FRIENDS OR FOES?

The Impact of Voluntary Sustainability Standards on Agricultural Exports of Developing Countries

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Friends or Foes? The Impact of Voluntary Sustainability Standards on Developing Countries' Agricultural Exports

Marcelo Dolabella and Mario Saeteros

Abstract

Private actors have been actively working on standards that certify products and their production processes to minimize negative externalities. The number of Voluntary Sustainability Standards (VSS) has been increasing over the last few decades, raising interest in understanding their impact on trade flows. Standards governing the production of agricultural commodities are especially crucial for developing countries as these goods often constitute a significant portion of their exports. Using a structural gravity model, we investigate how VSS certification affects exports for developing countries across eight highly traded commodities, and twelve VSS certification schemes from 2013 to 2021. Our analysis highlights how these effects differ across regions and explores in greater detail the effects on what is arguably the most exposed of these regions: Latin America and the Caribbean. The results indicate a positive and significant effect of VSS certification on exports, with a one percent increase in VSS coverage, resulting in an average 1.86% increase in export value. We also identify significant non-linear effects, leading to lower trade as certification coverage levels increase. On the commodity level, we observed positive and significant impacts on bananas, palm oil, tea, and cotton exports. Our findings also suggest that trade gains are larger for lower-income exporters trading with high-income destinations, with VSS playing an important role in reducing information asymmetries. Lastly, we observe that the proliferation of standards in the domestic market as well as increased competition from foreign countries reduce the positive effects associated with VSS adoption for the main agricultural producers.

JEL codes: F18, Q17, Q18, Q56

Keywords: Voluntary sustainability standards, private standards, international trade, developing countries, Latin America and the Caribbean

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1. *Introduction*

There is growing concern among firms, consumers, and governments about the environmental impact of production and consumption practices, especially in developed countries. These groups are seeking to understand and minimize the adverse effects that their purchasing habits may have on the production of these goods, both domestically or abroad.

Public and private actors have attempted to address these issues by requiring the adoption of best practices aimed at minimizing negative externalities for producing countries overall. Voluntary sustainability standards (VSSs) are private standards that require products and production processes to meet specific economic, social, and environmental sustainability metrics (UNCTAD, 2023). The standards and criteria established by the different VSSs are determined by private sector actors—companies, business and industry associations, or noncommercial nongovernmental organizations (NGOs) (Fiorini et al., 2020). These standards differ from the technical regulations set by public bodies—also known as nontariff measures (NTMs)—which generally aim to protect human, animal, or plant health and safety or the environment.[1]

Private standards have proliferated steadily in recent years. According to the Ecolabel Index, the number of VSS schemes has surged by over 150% in the last 20 years, such that more than 460 schemes were operational in 2022.[2] This paper aims to better understand the implications of adopting these standards for international trade, a crucial endeavor given the recent surge in their number. Understanding the economic VSS schemes is especially important for developing countries, where trade is a significant driver of inclusive economic growth and poverty reduction. Furthermore, VSS certification is most widespread among agricultural commodities, which are predominantly produced in developing countries (UNCTAD, 2023).

So, how do these standards affect international trade? Are they friends or foes? Several mechanisms have been identified as reasons why VSSs might have a positive or negative effect on trade. Trade is likely to increase if these certifications lead to i) a reduction in information asymmetries and transaction costs, ii) increased market access and demand through product differentiation and signaling, iii) price premiums, or iv) productivity gains. Conversely, the trade effects might be negative if i) certification, compliance, and monitoring costs are high, ii) there are technical barriers to implementation, iii) producers do not get a relevant share of the price premium, or iv) noncompliant producers are excluded from the market (UNCTAD, 2023). These forces influence market concentration, which can further exacerbate the effects on trade.[3] Thus, the overall trade effects of VSS adoption across countries and products is an empirical question.

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[1] First, VSS are voluntary, not mandatory (i.e., they are not legally binding). Second, they are private, created by NGOs or (associations of) companies. Third, they go beyond the realm of mandatory product regulation by setting standards for production processes (e.g., requiring the use of organic inputs) and other criteria (such as gender equality), compliance with which cannot be determined through physical inspection of the products in question (Fiorini et al., 2020).

[2] A similar pattern is also observed for public standards. These are regulated domestically and notified to the World Trade Organization (WTO) usually under the Technical Barriers to Trade (TBT) and Sanitary and Phytosanitary (SPS) agreements. Between 2001 and 2021, the total number of environmental notifications to the WTO increased fivefold, with the percentage of environmental-related notifications increasing from 7.8% in 2001 to 18.9% in 2021.

[3] For example, farmers from developing countries could easily be excluded from markets if they cannot make the necessary changes or afford the adjustment costs. If demand becomes dependent on VSS and the associated costs are high, small and medium-sized producers could be excluded from the market, leading to increased market concentration.

This paper contributes to the literature on VSSs and international trade in several ways. First, we estimate the relationship between VSSs and trade outcomes by considering a broader set of certifications, products, years, and countries than previous studies. We construct a larger, novel dataset, contemplating up to 161 exporters and 191 importers, 8 highly traded commodities (bananas, cocoa, coffee, cotton, palm oil, soybeans, sugarcane, and tea), and 12 VSS certification schemes between 2012 to 2021. Second, we focus on understanding the dynamics of this relationship for developing countries, where these crops are of greater relative importance within the broader economy. We do so by exploring how these effects vary across the developing world and for each individual crop. Third, we also pay special attention to Latin American and Caribbean (LAC) countries for several reasons. The region is one of the world's main suppliers of agricultural goods. It accounts for 14% of global food production and 45% of net international agrifood trade, and its agrifood systems account for up to half of total employment (FAO, 2021). In addition, the region is home to some of the world's most biodiverse ecosystems, containing approximately 60% of global terrestrial life and diverse freshwater and marine flora and fauna (UNEP, 2016). Recent concerns about the region's capacity to protect its environment, curb deforestation, and minimize damage from land use changes have hindered significant progress, particularly in advancing international trade agreements, such as the signing of the EU–Mercosur trade agreement. Fourth, we go beyond the current literature by including a more restrictive set of fixed effects and thereby controlling for additional unobserved factors. Fifth, we employ novel identification strategies to provide deeper insights into the relationship between trade and VSS adoption. These strategies reveal that the proliferation of standards dampens trade effects, market saturation of VSS reduces their impact, and there are non-linear effects of VSS adoption on trade.

We focus on the overall effects of VSSs on trade rather than other economic, environmental, and social outcomes. Literature assessing these dimensions typically compares treatment groups (certified households/producers) and control groups (uncertified households/producers) at the micro level. In most cases, positive or neutral effects are observed (Traldi, 2021; DeFries et al., 2017).[4] A similar pattern has also been observed for LAC as a whole (Arraya and Correa, 2023).[5] However, most of this evidence is case- and context-specific, and some crops, certifications, and countries are overrepresented while others are underrepresented. Given how hard it is to compare and generalize such findings, we take a bird's-eye view and focus our analysis on trade effects at the country-pair–commodity level.

The paper is organized as follows. In the next section, we review the available empirical evidence on how VSSs affect trade. In section 3, we present a descriptive overview of certification schemes and the production of selected commodities worldwide, with a focus on developing regions, particularly LAC. The estimation strategy we use is described in section 4. Section 5 presents some policy discussions and a way forward. Section 6 concludes.

[4] Analyzing 62 studies, Traldi (2021) finds a positive effect in 51% of them, a neutral effect in 41%, and a negative effect in 8%. DeFries et al. (2017) find similar results, with insignificant and positive effects dominating. After analyzing 24 studies, they find no significant difference in 58% of them, followed by a positive effect in 38% and a negative effect in 8%.

[5] See Ruben et al. (2009), Blackman and Naranjo (2012), Rueda et al. (2015), Schuster and Maertens (2015), Blackman et al. (2018), Dragusanu et al. (2022), Rana and Sills (2024), and Cezar et al. (2024), for case-specific studies for Latin American countries.

2. *Private Standards and International Trade—An Empirical Overview*

What does the empirical literature say about the effects of private standards on trade? First, most of the empirical work focuses on public regulations (Ghodsi et al., 2017; Cadot et al., 2018; Dolabella, 2020; Santeramo et al., 2023). Although a growing number of studies are assessing the impact of VSSs, the evidence remains rather scant. We summarize this evidence in table 1, focusing on country-level studies.[6]

Table 1. Summary of the Macro Evidence on the Effects of VSSs on International Trade

Authors	Standard	Commodities	Countries	Independent variable	Period	Findings
Masood and Brümmer (2014)	Global GAP	Bananas	Exp: 74 countries; Imp: EU27	Certified producers; harvested area	2010–2012	Positive effect
Ehrich and Mangelsdorf (2018)	IFS	Meat, fruits, vegetables, bakery, dairy, egg products, beverages	Exp: 87 countries; Imp: world	Number of certifications	2008–2013	Positive effect only for high- and middle-income countries
Andersson (2019)	Global GAP	50 fresh fruits and vegetables	Exp: 138 countries; Imp: EU—15 countries	Certified producers; harvested area	2008–2013	Positive and larger effect for low-income countries
Fiankor et al. (2020)	Global GAP	Bananas, apple, grapes	Exp: 163 countries; Imp: 156 countries	Certified producers; VSS coverage	2010–2015	Positive effect, less robust for bananas
Chen et al. (2020)	FSC, PEFC	Wood and furniture products	Exp and imp: 67 countries	Number of certifications	2009–2018	Positive effect for exporting countries
Grassnick and Brümmer (2021)	UTZ	Cocoa	Exp: 42 countries; Imp: 38 largest importers	VSS coverage	2010–2016	Positive effect for cocoa beans and paste, negative for cocoa butter
Bemelmans et al. (2023)	Global GAP, Fairtrade Int., Rainforest Alliance, UTZ, 4C, RSPO, Organics	Bananas, coffee, tea, cocoa, and palm oil	Exp: 110 countries; Imp: 183 countries	VSS coverage	2012–2018	Positive effect for bananas, coffee, and tea
Chen et al. (2024)	RTRS	Soybeans	Exp: 89 countries; Imp: 40 countries	Certified Production; Area harvested	2012-2019	Negative effect (area) Non-significant effect (quantity)

Note: VSS coverage represents the share of the certified area over the crop-specific total production area. Acronyms: FSC—Forest Stewardship Council; PEFC—Program for the Endorsement of Forest Certification Schemes; RTRS—Round Table on Responsible Soy Association; and RSPO—Roundtable for Sustainable Palm Oil.

The first key takeaway is that most studies find VSSs to have a positive impact on trade, suggesting that the trade-enhancing effects dominate. However, it is worth noticing that although most of these studies cover multiple countries and commodities, they tend to focus on only one standard, particularly Global GAP. Bemelmans et al. (2023) were the first to expand the sample of commodities and VSS schemes and

[6] Other studies are concerned with microevidence, which usually assesses the effects of adopting one standard in one particular crop and country, comparing a sample of certified and noncertified farms. This is not covered in this study. For a review of this literature, see Elamin and Fernandez (2020).

combine them into a single analysis. They find positive effects for bananas, coffee, and tea. We extend their analysis by including more commodities and VSS schemes.

3. VSS Adoption and Largest Producers—Descriptive Evidence

Understanding the basic characteristics of VSS adoption worldwide is critical to interpreting the analyses that follow. In this section, we present a comprehensive overview of the data provided by the Research Institute of Organic Agriculture (FiBL) and the International Trade Centre (ITC). The data consists of production and harvested hectares by country for eight commodities: bananas, cocoa, coffee, cotton, palm oil, soybeans, sugarcane, and tea. It combines information from the 12 largest certification schemes: 4C, the Better Cotton Initiative (BCI), Bonsucro, Cotton made in Africa (CmiA), Fairtrade International, GLOBALG.A.P., IFOAM Organics International, ProTerra Foundation, Rainforest Alliance, the Round Table on Responsible Soy Association (RTRS), the Roundtable on Sustainable Palm Oil (RSPO), and UTZ.

Before exploring the VSS data, it is worth highlighting a few stylized facts about the global production of and trade in these commodities. Table 1 shows the share of the top five producers of each commodity in global production, along with their ranking among the world's largest exporting countries of the commodity in question in parentheses.[7] For instance, the largest banana growers were India (19.4%) and China (7.3%), but in export terms, these countries ranked only 22nd and 34th, respectively, as their domestic markets absorb much of their production. The Philippines, Indonesia, Ecuador, and Brazil follow, each of which accounts for about 5% of global banana production. Another important takeaway from this table is that apart from the US, which is a major producer of cotton and soybeans, all other producers are developing countries.

Table 1. Largest Producers of Selected Agricultural Commodities and Their Respective Export Rank, 2013–2021

(Share of global production and rank among largest exporting countries)

Crop	*1st-largest producer*	*2nd-largest producer*	*3rd-largest producer*	*4th-largest producer*	*5th-largest producer*
Bananas	IND: 19.4% (22)	CHN: 7.3% (34)	PHL: 5.8% (2)	IDN: 4.8% (55)	**ECU: 4.6% (1)**
Sugarcane	**BRA: 39.7% (1)**	IND: 19.2% (5)	CHN: 5.9% (7)	THA: 5.3% (2)	PAK: 3.9% (48)
Cocoa	CIV: 37.3% (1)	GHA: 17.1% (3)	IDN: 13.3% (4)	CMR: 5.8% (10)	NGA: 5.8% (9)
Coffee	**BRA: 31.2% (1)**	VNM: 16.1% (2)	**COL: 8% (3)**	IDN: 7.3% (7)	ETH: 4.9% (10)
Cotton	CHN: 25.1% (31)	IND: 24.8% (2)	USA: 13% (1)	PAK: 7.3% (23)	**BRA: 6.8% (3)**
Palm oil	IDN: 58% (1)	MYS: 25.9% (2)	THA: 3.7% (10)	NGA: 2.4% (57)	**COL: 1.9% (8)**
Soybeans	USA: 33.1% (2)	**BRA: 32.1% (1)**	**ARG: 15.5% (3)**	CHN: 4.4% (11)	IND: 3.5% (12)
Tea	CHN: 43% (1)	IND: 21.4% (4)	KEN: 8.4% (2)	LKA: 6.3% (3)	TUR: 5.2% (35)

Source: FAO and BACI data. Note: Each country code is followed by that country's share in global production for each commodity from 2013 to 2021. The country's position in the ranking of the largest exporters of each commodity is shown in parentheses. LAC countries are shown in bold.

With this overview in mind, we now analyze how certifications and certified production have spread across the developing world, which accounted for nearly all VSS-certified land in 2021 (97%).[8] Cotton, coffee, and cocoa are the most certified commodities, representing approximately 60% of the total certified global area. Certifications can be divided into product-specific schemes, such as the BCI (cotton), Bonsucro (sugarcane), and RTRS (soybeans), which only certify a single commodity, and those that certify a wide range of products, such as Fairtrade International, Organic, and the Rainforest

[7] See Table B1 to B8 in the annex for detailed statistics of the main producers and exporters in each commodity.

[8] We classify countries as developing countries according to the World Bank income classification (Fantom et al. 2016).

Alliance. In general, each commodity is certified by three to five VSS schemes, with the top three accounting for almost all certified land in each commodity (see table 2). In 2021, 25.7 million hectares were certified in the developing world. In LAC, 9.5 million hectares were certified, with sugarcane, coffee, and soybeans accounting for the largest certified areas, totaling approximately 70% of all certified land in the region.

Table 2. Main VSS Schemes by Commodity

(Developing countries and LAC, 2021)

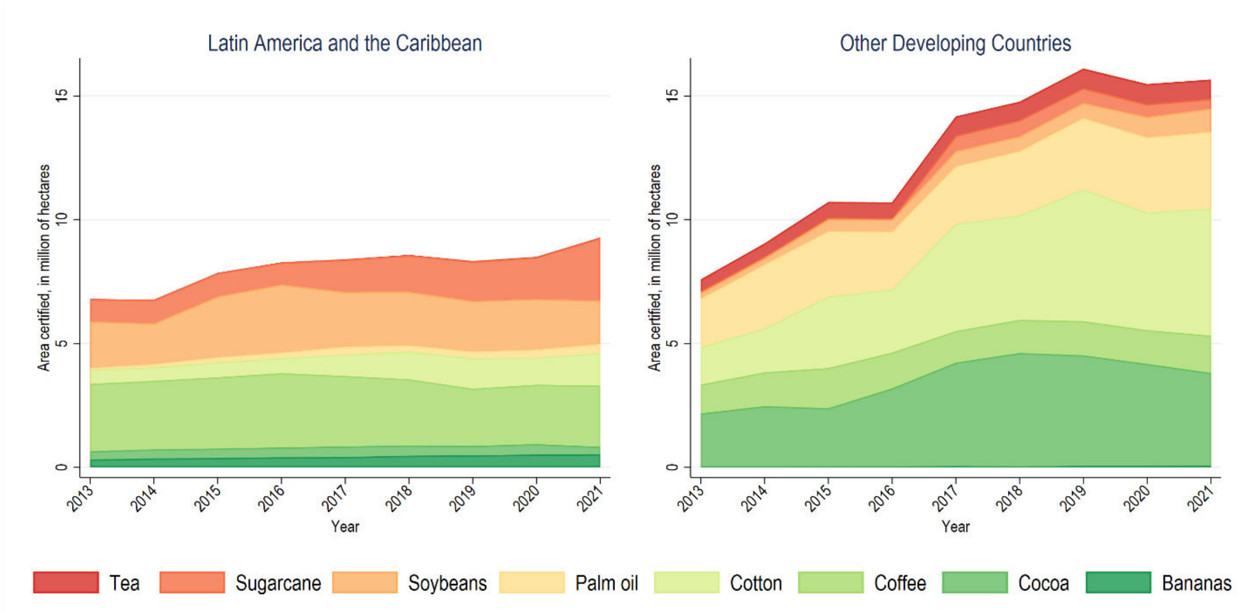
	Harvested area (million ha)	*1st-largest certifier*	*2nd-largest certifier*	*3rd-largest certifier*
Developing world	**25.69**	**BCI (16.7%)**	**RSPO (13.1%)**	**Organic (11.4%)**
Cotton	6.59	BCI (65.0%)	CmiA (25.9%)	Organic (8.6%)
Cocoa	4.44	UTZ (45.9%)	Fairtrade Internat. (33.1%)	Rainforest Alliance (11.3%)
Coffee	4.03	Fairtrade Internat. (26.1%)	Organic (19.8%)	4C (19.7%)
Palm oil	3.49	RSPO (96.0%)	Rainforest Alliance (3.1%)	Organic (0.9%)
Sugarcane	2.90	Bonsucro (63.1%)	ProTerra Foundation (31.0%)	Organic (3.7%)
Soybeans	2.69	RTRS (49.2%)	Organic (28.6%)	ProTerra Foundation (22.2%)
Tea	0.92	Rainforest Alliance (70.7%)	Organic (14.5%)	Fairtrade Internat. (10.9%)
Bananas	0.62	GLOBALG.A.P. (50.3%)	Rainforest Alliance (27.3%)	Organic (15.6%)
LAC	**9.53**	**Bonsucro (18.6%)**	**BCI (13.7%)**	**RTRS (12.7%)**
Sugarcane	2.54	Bonsucro (69.7%)	ProTerra Foundation (25.0%)	Organic (3.4%)
Coffee	2.50	Fairtrade Internat. (30.2%)	UTZ (19.7%)	4C (19.3%)
Soybeans	1.76	RTRS (69.0%)	ProTerra Foundation (30.1%)	Organic (0.9%)
Cotton	1.32	BCI (98.8%)	Organic (1.2%)	-
Bananas	0.55	GLOBALG.A.P. (50.3%)	Rainforest Alliance (29.2%)	Organic (12.8%)
Cocoa	0.49	Fairtrade Internat. (34.2%)	Organic (28.7%)	UTZ (27.1%)
Palm oil	0.35	RSPO (89.1%)	Rainforest Alliance (9.1%)	Organic (1.8%)
Tea	0.02	Rainforest Alliance (97.6%)	Organic (2.4%)	-

Source: Data from the FiBL and the ITC. Note: Panel A includes all developing countries, including those in LAC. Panel B considers all LAC countries.

An analysis of the evolution of certified area over time shows a clear upward trend in both LAC and other developing regions (figure 1). From 2013 to 2021, the total certified area in LAC increased by 37%, from 6.8 to 9.3 million harvested hectares. Conversely, in other developing regions, this figure more than doubled, skyrocketing from 7.6 to 15.7 million harvested hectares. Furthermore, the composition and trajectory of certified commodities vary significantly across regions. LAC certifies most of the sugarcane, soybeans, coffee, and bananas, while other regions produce more cotton, palm oil, cocoa, and tea under VSS schemes. In LAC, sugarcane was the crop that experienced the largest increase in certified area, going from 0.9 to 2.53 million certified hectares. In contrast, the certified area of coffee decreased, especially under the 4C certification. Cotton has also gained ground (mainly under the BCI), especially in Brazil.

Figure 1. Evolution of Harvested Area under VSS Schemes

(LAC and other developing countries, 2013–2021)



Source: Data from the FiBL and the ITC. Note: This figure takes the total certified area into account and does not consider the fact that a single hectare might have been certified more than once. "Other developing countries" refers to all developing countries except those in LAC.

Although informative, the data on the total certified area is prone to double counting. Some producers certify their production under two or more labeling schemes. To address this issue, we follow the literature and consider a minimum certified production area (i.e., the area covered by the most widespread VSS) at country-product level, as in Bemelmans et al. (2023).[9] Global VSS coverage varies substantially across commodities. In 2021, Soybeans and bananas were the crops with the lowest VSS coverage worldwide, as just 1.7% and 2.7% of production were certified, respectively. Sugarcane (9.0%), palm oil (11.4%), coffee (13.1%), and tea (14.2%) follow, with moderate VSS coverage ratios. Cotton and cocoa were the most certified commodities with at least 20.3% and 21.5%, respectively, of their total area harvested certified.

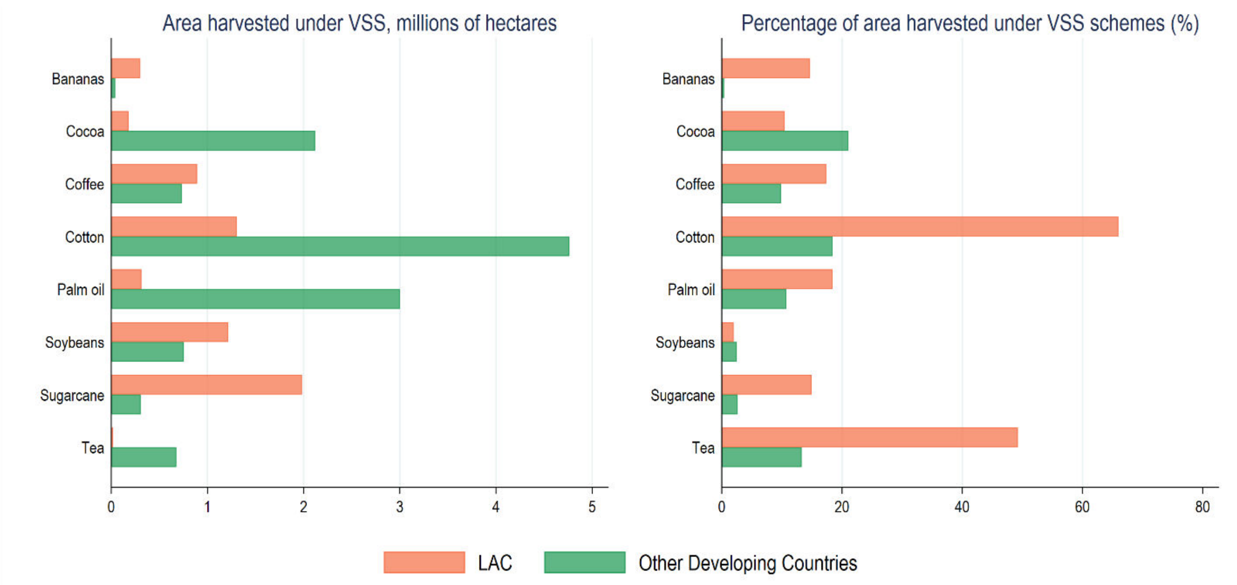
Figure 2 shows how the minimum certified area in LAC compares to the rest of the developing world. The first and second panels show the harvested area and its share in total production (VSS coverage ratio), respectively, for both regions. The results confirm that sugarcane, cotton, soybeans, and coffee are the most certified commodities in LAC. In terms of the VSS coverage ratio, cotton is the frontrunner: production levels are significant and more than 65% of the harvested area is certified. Tea follows with a coverage of 49%, despite having a smaller harvested area. The remaining commodities have varying degrees of certification in 2021, ranging from 2% of total soybean production to 18% for palm oil.

The data on the certified area and the total harvested area for those eight commodities allows us to calculate the VSS coverage ratio for each country (figure 3). These results reveal significant heterogeneity

[9] As an illustrative example, suppose that in a particular country the total harvested area of coffee was 100 hectares and there were three labels certifying coffee production. Label A, certified 10 hectares, label B, 4 hectares and label C, 2 hectares. This country coverage ratio considering the minimum certified area is calculated by taking the largest certified area (10 hectares from label A) and dividing by the total harvested area, which gives us a coverage ratio of 10%. See annex A for the formula used to calculate it.

between and within developing regions. This is particularly pronounced in Africa, where only a few countries certify most of their production while others certify none. Central and South American countries such as Costa Rica, Colombia, Ecuador, and Peru have notably higher coverage ratios. As shown above, European countries are not among the largest producers of these commodities (table 1). However, a significant proportion of what little they do produce appears to be certified to a private standard.

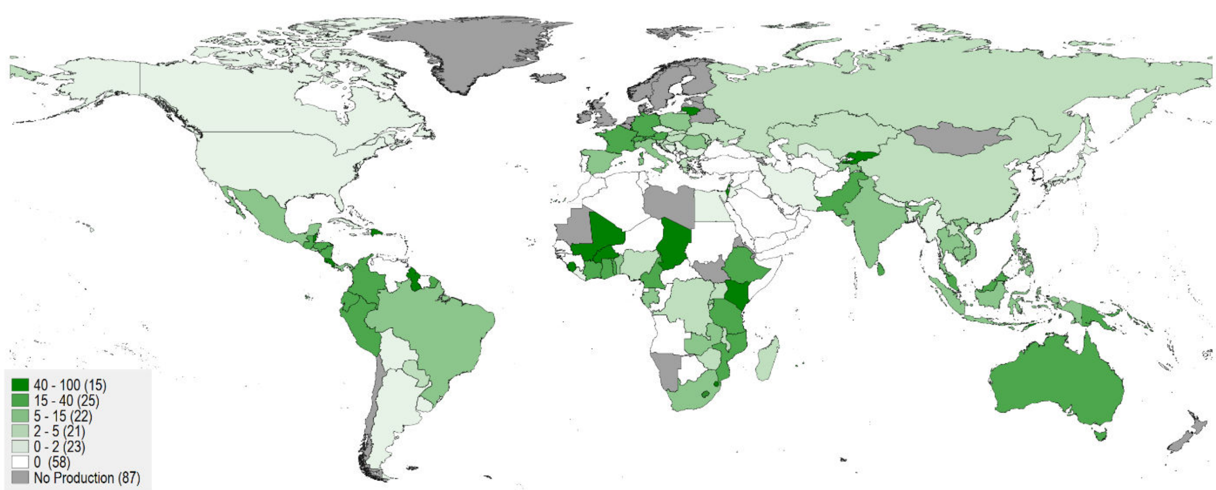
Figure 2. Harvested Area for Different Commodities, 2021



Source: Data from FiBL and the ITC. Note: This figure considers the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year).

Figure 3. VSS Coverage by Country

(% of VSS-certified area of total harvested area, 2021)



Source: Authors based on VSS data from FiBL and the ITC and harvested area data from FAO. Note: this figure considers the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year). The numbers in parentheses represent the number of countries in each bin.

Although this data provides an initial assessment of the overall VSS coverage ratio, crop specialization and differing land use intensities for each crop prevent us from drawing much more insight at this point. In annex B, we show how the coverage rate varies by country and by commodity type. The largest coverage ratios for banana production are in Costa Rica, Honduras, Guatemala, and Ecuador. The figure also reveals that a large share of Brazil's cotton production is certified. In contrast, Brazil and Argentina have very low VSS coverage ratios for soybeans (2.5% and 1.2%, respectively). The distribution of VSS coverage ratio among developing countries reveals that the median producer has a coverage ratio that is close to zero (table 3, panel A). However, after examining country-year combinations in which at least some areas are VSS-certified, we find that the median country-year VSS coverage ratio ranges from 2% for soybeans to 22% for cocoa (table 3, panel B).

Table 3. Distribution of VSS Coverage by Commodity

(VSS coverage distribution statistics for developing countries, 2013–2021)

	Minimum	25th percentile	Median	75th percentile	Maximum	Mean	Standard deviation	Count (producer year)
Panel A: VSS coverage ratios of developing country producers								
Bananas	0	0	0	0.01	100.0	3.9	13	936
Cocoa	0	0	0.7	22.6	100.0	16.6	28	516
Coffee	0	0	0.9	20.8	100.0	14.0	24	648
Cotton	0	0	0	2.0	100.0	9.4	24	728
Palm oil	0	0	0	10.1	100.0	11.3	23	396
Soybeans	0	0	0	0.1	100.0	1.8	10	688
Sugarcane	0	0	0	0.2	100.0	4.7	15	770
Tea	0	0	4.1	30.8	100.0	21.5	32	378
Panel B. Positive VSS coverage ratios of developing country producers								
Bananas	0.001	0.2	2.0	26.3	100.0	14.8	22	246
Cocoa	0.031	5.0	22.0	45.5	100.0	31.9	32	268
Coffee	0.022	5.5	16.8	35.3	100.0	25.4	27	358
Cotton	0.001	2.7	11.9	51.1	100.0	29.8	35	229
Palm oil	0.000	5.1	17.1	44.0	100.0	28.6	30	156
Soybeans	0.003	0.3	1.1	3.3	100.0	6.3	17	195
Sugarcane	0.011	0.4	6.1	17.0	100.0	15.2	24	236
Tea	0.024	4.5	21.1	58.4	100.0	33.9	34	240

Source: Authors based on VSS data from the FiBL and the ITC and harvested area data from FAO. Note: Panel A shows the distribution of VSS coverage ratios across all countries, while panel B shows the distribution of VSS for all countries with a positive coverage ratio. We consider the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year). The number in parentheses represents the number of countries in each bin.

4. Empirical Strategy and Econometric Issues

To evaluate the impact of VSS schemes on trade, we employ a structural gravity model.[10] Following the literature, we introduce a measure of VSS coverage in the exporting economy into the gravity equation (Anderson, 2019; Fiankor et al., 2020; Bemelmans et al., 2023). The baseline specification applies a Poisson pseudo-maximum-likelihood (PPML) estimator over nine years, from 2013 to 2021, using the following specification:[11]

[10] See Yotov et al. (2016) for the derivation of the theory grounded gravity model.

[11] We follow the literature and employ PPML because of its convenient properties of dealing with zero trade flows and heteroskedasticity. The estimator does not drop zero trade observations because no transformation of the dependent variable is required and it is robust to different patterns of heteroskedasticity in the residuals, differently from OLS. See Santos Silva and Tenreyro (2006).

$$X_{ijkt} = exp\big[\beta_1 VSS_{ikt-1} + \beta_2 ln\big(1 + Tariff_{ijkt-1}\big) + \beta_3 ln(Y_{ikt}) + \beta_4 NTM^m_{ijkt-1} + \beta_5 NTM^x_{ijkt-1} + \beta_6 NTM^x_{ikt-1} + \beta_7 ln(Remoteness_{ikt}) + \omega_{jkt} + \varphi_{ijt}\big]\varepsilon_{ijkt}$$

where X_{ijkt} is the trade flows (in US dollars) of product *k* from exporting country *i* to importing country *j* in year *t*; VSS_{ikt} is the share of minimum certified land area in the total harvested area of product *k* in country *i* in year *t*. In addition, we control for the following variables: Y_{ikt} is the domestic output of product *k* in tons; $Tariff_{ijkt}$ is the bilateral ad valorem tariff on product *k* at time *t*; NTM^m_{ijkt} , NTM^x_{ijkt}, NTM^x_{ikt} are three sets of NTM prevalence scores covering, respectively, measures imposed by country *j* on exporting country *i* for product *k*; measures imposed by country *i* on importing country *j* for product *k*; and measures imposed by country *i* on the world for product *k*.[12,13] These are mandatory public technical and nontechnical measures imposed by the importer or/and the exporter, respectively. An exporter remoteness index is included in its natural logarithm form, $ln(Remoteness_{ikt})$. We also include a set of fixed effects to control for other unobservable and multilateral resistances: φ_{ijt} country-pair-time and ω_{jkt} importer-product-time fixed effects.[14] ε_{ijkt} is the error term.

We conduct our baseline estimations using a refined sample of exporters. As mentioned earlier, we focus our analysis on developing countries.[15] Consequently, our sample is restricted to exporting nations within this category. We then further refine our sample of exporters by selecting only countries that significantly contribute to global supply—that is, those that accounted for more than 0.5% of global production between 2013 and 2021. These major producers represented at least 92% of total production and 89% of the total harvested area during the study period.[16] This process prioritizes countries with significant production levels.[17] As a result, our main estimations are conducted on a sample of 57 exporters and 191 importers.[18] To ensure robustness, we also run these analyses on the full dataset, which encompasses 161 exporters and 191 importers.

A few points are worth discussing before moving forward. The first concerns the potential endogeneity of our results. This could arise from two sources: i) reverse causality and ii) omitted variable bias. The former pertains to the fact that larger trade flows could generate higher revenues, prompting more farmers to adopt VSSs. To attenuate this risk of reverse causality, we lag our right-hand-side variable by one period so that higher revenue from trade is less likely to affect the amount produced under VSS schemes the

[12] The prevalence score reflects the average number of NTMs that apply to a given commodity. It is calculated at the HS 6-digit product level and aggregated as a simple average for each commodity. Nontariff import measures imposed by the importing country to the world were not included because they are already accounted for in the importer-product-time fixed effects. See annex A for details.

[13] For robustness, we also estimate this equation without NTMs as controls. Their inclusion forces many African and Middle Eastern countries out of the sample due to missing NTM data. In LAC, Dominican Republic and Haiti are the main countries with missing data. See annex A for details.

[14] A detailed description of the data sources can be found in the appendix.

[15] We consider all LAC nations in the sample of developing countries, even though some LAC countries have been classified as high-income countries (Fantom et al., 2016), namely Uruguay, Panama, Trinidad and Tobago, Guyana, Bahamas, Barbados, and St. Kitts and Nevis. These countries account for only 0.5% of the total certified area in LAC in 2021.

[16] See tables B1 to B8 in the annex for detailed statistics on the main producers and exporters of each commodity.

[17] This sample restriction also mitigates a potential measurement error concern in our variable of interest, VSS coverage. For some countries and labels, information is not shown if the numbers of partners/producers fall below a certain threshold. Since large producing countries also tend to certify larger areas (correlation, 0.482), the missing data is significantly lower for these countries. In addition, the fact that we construct the coverage of VSS as the coverage of the most widespread VSS also mitigates these measurement error concerns.

[18] Not all 57 exporting countries are major producers of all 8 commodities.

previous year. Following this reasoning, we do the same for control variables that are subject to reverse causality.

Another potential threat to our causal inference is potential omitted variable bias, that is, the omission of variables that correlate with our variable of interest (VSS coverage). To address this issue, we first include a comprehensive set of fixed effects. Country-pair-time fixed effects control for variables that are constant for each country pair—such as distance, contiguity, common language, and common borders—but also for variables that are specific to each country pair but vary over time, such as the existence of regional trade agreements or exchange rates.

Another important set of controls are the so-called multilateral resistance terms (MRTs), which take into account the cost of trading with all other potential trading partners. Failure to control for these terms results in a classic case of omitted variables bias (Anderson and Van Wincoop, 2003; Shepherd, 2016) as their construction means they are correlated with trade cost. A common way to avoid this bias and control for MRTs is to include importer-product-time and exporter-product-time fixed effects. We include the former, which also captures variables such as importer GDP, multiple regulations from country *j* that affect product *k*, and changes in these over time. However, we cannot include exporter-product-time fixed effects because these are perfectly collinear with our variable of interest. Therefore, we include additional controls in our baseline specification that vary along the same dimension, such as the total production of each commodity, the regulations that each exporter country applies to exports of the commodity (NTMs), and a remoteness index. In the literature, remoteness is usually calculated in the country-time dimension by using GDP weights (Bacchetta et al., 2012; Head and Mayer, 2014). We adapt this variable to make it exporter-product-time-specific by using product-level domestic absorption instead of GDP. In sum, the variable measures the exporter's average weighted distance from its trading partners, where the weights are the partner countries' shares in the global absorption of product *k*.[19]

To further address reverse causality and omitted variable bias, we implement an additional identification strategy, an instrumental variable estimator. Here, we follow the literature and define the instrument as the average VSS coverage of all neighboring countries (Ehrich and Mangelsdorf, 2018; Fiankor et al., 2020; Bemelmans et al., 2023). This instrument satisfies the relevance condition because VSS adoption is likely to be correlated across neighboring countries due to similar climate conditions, knowledge spillovers, and cost-sharing mechanisms. It is also unlikely that VSS adoption in neighboring countries will drive the export performance of the country in question (Ehrich and Mangelsdorf, 2018).

In contrast to the above literature (Ehrich and Mangelsdorf, 2018; Fiankor et al., 2020; Bemelmans et al., 2023), we do not estimate an IV-PPML estimator because this would entail the incidental parameter problem and therefore cannot be used to estimate models with fixed effects (Santos Silva and Tenreyro, 2022). We opted to take a step back and estimate the linear IV-ordinary least square (OLS) model. This has the advantage of addressing potential endogeneity while being immune to the incidental parameter problem under a large set of fixed effects. However, we need to be aware of two potential problems when estimating a gravity model with OLS. The first is the potential bias associated with the truncation of all

[19] We calculate this variable as follows: $Remoteness_{ikt} = \sum_{j=1}^{J} \frac{distance_{ij}}{[(Prod_{jkt}+Imp_{jkt}-Exp_{jkt})/Global\_Absoption_{kt}]}$, where the domestic absorption of each country is calculated using the production, imports, and exports of each commodity in metric tons. The sum of the domestic absorption of all countries gives us $Global\_Absoption_{kt}$, which is used as the denominator in the calculation of shares. This term is used to weight the distance between all partners.

observations with zero trade, stemming from the impossibility to calculate the natural log of zero. The second problem is that heteroscedasticity might introduce bias into the results of the log-linearized gravity model, primarily due to the multiplicative nature of the error term in the stochastic gravity model. To mitigate the zero-trade issue, we add a constant of 1 to the trade values when estimating the IV-OLS model. We compare these results with those of the OLS and PPML estimators. The next section contains our main findings.

5. *Empirical Results*

We present the results using the three approaches discussed above: OLS, the standard estimator for structural gravity models; PPML; and the instrumental variable-ordinary least square (IV-OLS) estimator. This allows us to compare the estimates from different models and explore potential biases. The results are shown in table 4.

Table 4. Trade Effects of VSS Adoption

(OLS, IV-OLS, and PPML)

VARIABLES	(1) OLS	(2) IV-OLS	(3) PPML	(4) OLS	(5) PPML
VSS_{ikt-1}	0.0188***		0.0186***	0.0465***	0.0319***
	(0.0018)		(0.0032)	(0.0047)	(0.0059)
VSS_{ikt}		0.0486***			
		(0.0079)			
VSS^2_{ikt-1}				-0.0004***	-0.0002***
				(0.0001)	(0.0001)
log(1+tariffs$_{ijkt-1}$)	-2.4956***	-3.2833***	-6.5804***	-2.4170**	-6.7002***
	(0.9603)	(0.9824)	(1.0704)	(0.9531)	(1.0688)
log(Production$_{ikt}$)	1.3568***	1.3121***	1.4377***	1.3236***	1.4031***
	(0.0414)	(0.0408)	(0.0626)	(0.0414)	(0.0636)
ln(Remoteness$_{ikt}$)	0.1206*	0.2737***	0.1497	0.1027	0.1225
	(0.0698)	(0.0822)	(0.1002)	(0.0693)	(0.0982)
NTM^x_{ikt-1}	0.1181***	0.1457***	0.0190	0.1142***	0.0157
	(0.0143)	(0.0166)	(0.0194)	(0.0142)	(0.0195)
NTM^x_{ijkt-1}	-1.3227***	-1.4983***	-0.5616**	-1.2372***	-0.5108**
	(0.3101)	(0.3176)	(0.2573)	(0.3069)	(0.2574)
NTM^m_{ijkt-1}	0.0357	0.0711	-0.2697	0.0170	-0.2538
	(0.1557)	(0.1570)	(0.1693)	(0.1571)	(0.1678)
Constant	-20.2355***		-9.0745***	-19.3024***	-7.6771**
	(2.2763)		(3.1014)	(2.2558)	(3.0043)
Observations	115,200	114,944	66,692	115,200	66,692
SW F-Test		650,12			
SW pval		0,00			
Import-Product-Time FE	YES	YES	YES	YES	YES
Countrypair-Time FE	YES	YES	YES	YES	YES

Note: Robust country-pair-product clustered standard errors in parentheses; ***, **, * denote significance at 1, 5, and 10 percent, respectively. The dependent variable is bilateral trade transformed to ln(1+trade) in columns 1, 2, and 4. For columns 3 and 5, the dependent variable enters in levels. The independent variable is the coverage ratio of VSS, under different forms. Log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMS enter as controls. Sample restricted to consider only exporters which are top producers from developing countries.

In columns 1 to 3, our main explanatory variable is presented as VSS_{ikt-1}, which ranges from 0 to 100 and can be interpreted as semi-elasticity. As shown in table 4, the coefficient for the minimum certified area is positive and statistically significant, as previously observed in the literature. On average, a 1-percentage point increase in the share of the certified area in production increases the value of exports by 1.86% (column 3, PPML estimator). Our OLS estimator is of similar magnitude, suggesting that the heteroscedasticity bias might not be strong (column 1). Finally, we observe that switching from OLS to IV-OLS increases the magnitude of the parameter by a factor of 2.6 to a point estimate of 4.86%.[20] These values suggest that our OLS and PPML estimators may be biased downward. Our main findings align with those of Bemelmans et al. (2023), who report average trade effects ranging from 1.8% to 3.3%. Moreover, the signs and magnitudes of the control variables are in line with our expectations.[21]

Furthermore, our results reveal a novel and significant non-linear relationship between VSS and exports. By incorporating a quadratic term of $VSS_{(ikt-1)}$, we observe positive linear and negative quadratic coefficients, both significant at 1%, in both OLS and PPML (columns 4 and 5). This finding suggests that while an increase in the share of certified areas produced corresponds to increased trade, the marginal benefits of additional certifications diminish as certification levels rise. This nonlinearity implies that countries with lower certification coverage see a bigger boost in exports when their VSS coverage increases. However, for countries with high coverage ratios, adding another percentage point has a smaller impact on trade.

Now, we turn to assess the robustness of these findings. We start by changing the functional form of our dependent variable to $\log(1 + VSS_{ikt-1})$. This specification allows the results to be interpreted as elasticities (See table C2 in Annex C). Likewise, a 1% increase in the share of certified land in production is associated with a 0.457% increase in the value of certified exports, ceteris paribus.[22] As before, the OLS estimator is similar in magnitude to the PPML, while the IV-OLS estimator gives us a larger point estimate that is almost twice the size of our OLS estimate.[23]

These results are robust to alternative sample estimations. Changing the sample of exporters does not affect the direction and significance of the effect and has only a slight effect on magnitude. The impact on the top producer of the commodity is larger than for a sample of all countries. This is also confirmed by a model that weights observations by total production or harvested area under VSS. The effects also seem to be larger for exporters in developing countries, as the inclusion of all producers slightly reduces our estimate. As a further robustness check, we do not consider NTMs as controls because their inclusion forces many African and Middle Eastern countries out of the sample due to missing NTM data. Not including these controls increases the number of observations but does not affect the overall significance and magnitude of the estimates. See the robustness section of annex C for details (table C3).

[20] Our instrument passes the instrument validity assumption: by evaluating the SW first-stage F p-value, we reject the null hypothesis of a weak instrument. The test is used as a diagnostic for whether a particular endogenous regressor is "weakly identified." For further details, see Sanderson and Windmeijer (2016).

[21] Of all the models we estimated, only tariffs and domestic output as consistently significant. Domestic output, the exporter remoteness index, and prevalence measures imposed on the world enhance trade, while bilateral ad valorem tariffs and prevalence measures imposed on importing countries hinder bilateral trade.

[22] This result is consistent with that obtained by Fiankor et al. (2020), who report an average trade effect of 0.45% for apples, bananas, and grapes.

[23] Adding a smaller constant to the dependent variable, $\ln(0.01 + VSS_{ikt-1})$, also yields significant results at the 1% level. However, the magnitude of the estimates from columns 4 to 6 are 55% to 29% smaller. For simplicity, the results are not included here but are available upon request.

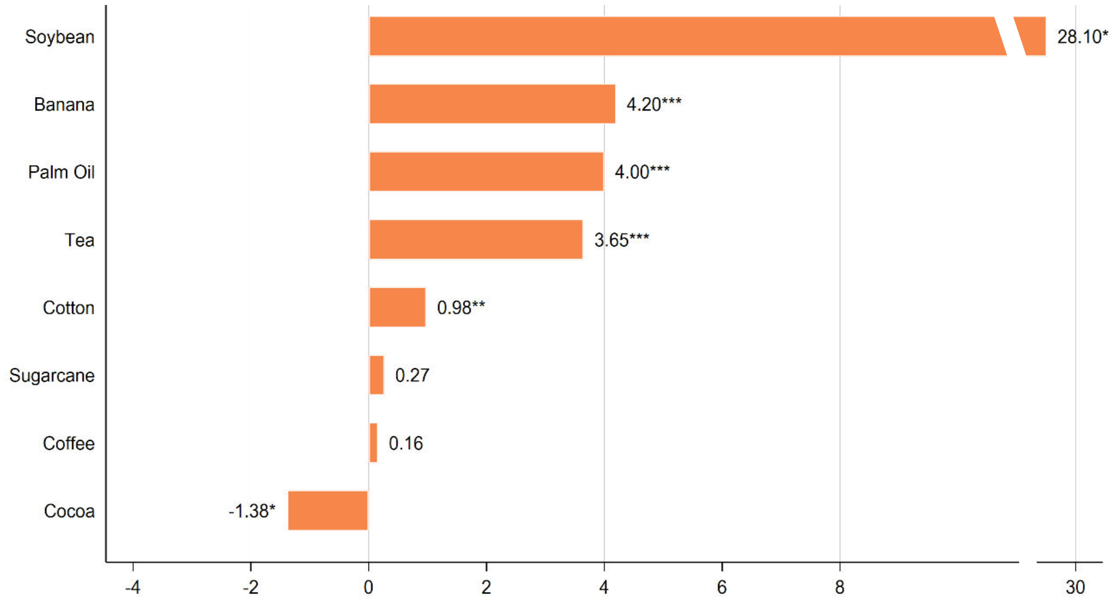
Given that data on VSS for some labels might be subject to confidentiality issues for some country-crop-years with low production levels (see the discussion in annex A), we run three alternative specifications to assess the robustness of our main results. First, we assess two alternative definitions of VSS coverage: i) a maximum VSS coverage by adding up all certified areas across labels, and ii) an average for VSS coverage by taking the mean of all certified areas across labels. The maximum coverage can be interpreted as a potential overestimation of the VSS harvested area, and the average as an underestimation. As expected, when we overestimate the VSS coverage, the effect drops to 1.2%. When we underestimate it, it increases to 3.3% (annex C, table C4). Second, we modify our baseline specification by eliminating the panel dimension and estimating a cross-sectional difference model. We do so by averaging the three initial and three final years of our dataset, taking into account the differences in VSS coverage, exports, and all other variables. Third, we select only one label per commodity, the one with the least number of missing data points, to construct our coverage variable. In general, the results support the positive effects of VSS adoption on trade (annex C, table C5).

A significant amount of heterogeneity remains concealed in the findings. To begin to understand these effects, we modify our main specification by interacting VSS_{ikt-1} with product dummies. Table 2 summarizes the PPML estimates for the crop-specific coefficients for the main producers of developing regions. We found that a 1-percentage-point increase in the share of minimum certified area raises exports of bananas (4.2%), palm oil (4.0%), tea (3.6%), and cotton (1.0%), respectively, with 95% confidence. Robustness estimations confirm the positive results, especially for bananas and palm oil.[24] The robust and positive effect for bananas can be explained by the low global VSS coverage and the possible first-mover advantage (Bemelmans et al., 2023; Henson and Humphrey, 2010). VSS soybean certification appears to have the largest effect, although the point estimate is relatively imprecise due to large standard errors. When all producers are considered, the positive effect is significant at 99% confidence but substantially smaller (5.7%). When a weighted PPML is run using the harvested area as the weight, we find no significant effect. This suggests that the positive effects of soybean certification might be larger for smaller producers. Estimates for cocoa are also less precise but point to negative or neutral trade effects.[25]

[24] See annex C, table C6 for robustness estimations on the effects of VSS adoption by commodity.

[25] The results for cocoa certification appear to be less robust. The inclusion of NTMs as controls forces four main producers out of the sample due to missing data, namely Nigeria (5th-largest producer), Dominican Republic (9th-largest producer), Uganda (12th-largest producer), and Sierra Leone (15th-largest producer). Changing the set of controls by excluding NTMs turns the weak negative effect into a nonsignificant effect. This also happens when other smaller producers are included in the sample.

Figure 4. Trade Effects of VSS Adoption by Commodity



Note: ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is the bilateral trade in levels. The independent variable is the VSS coverage ratio, which is interacted with product dummies. The log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMs are included as controls but are not displayed here. The sample is restricted to exporters that are top producers from developing countries.

At the commodity level, our results are consistent with some studies and contrast with others. Fiankor et al. (2020) and Bemelmans et al. (2023) also found positive effects for bananas and tea. Our study shows a positive effect for palm oil, whereas Bemelmans et al. (2023) found no effect. We did not find coffee certification to have significant effects on trade, in contrast to the positive effects observed by Bemelmans et al. (2023). For soybeans, Chen et al. (2021) reported a negative effect, which differs from our results. Last, our findings contradict those of Grassnick and Brümmer (2021), who suggest a positive effect for cocoa. It is essential to note that there is a significant variation in the sample composition across these studies, including the number of labels, years, and countries covered.

Table 5. Trade Effects of VSS Adoption; PPML by Crop and Exporting Region

Variables	Latin America and the Caribbean	East and South Asia and Pacific	Sub-Saharan Africa	Other regions
		PPML		
(VSS_{ikt-1}) x Banana	0.0210***	1.7804	2.0953***	33.6113**
	(0.0060)	(1.1366)	(0.3148)	(14.2987)
(VSS_{ikt-1}) x Sugarcane	-0.0741**	0.0489**		
	(0.0367)	(0.0235)		
(VSS_{ikt-1}) x Cocoa	0.0030	0.1339**	-0.0284**	
	(0.0103)	(0.0659)	(0.0117)	
(VSS_{ikt-1}) x Coffee	0.0059	0.0214	0.0020	
	(0.0078)	(0.0151)	(0.0084)	
(VSS_{ikt-1}) x Cotton	-0.0021	-0.0151	-0.0097***	0.0175
	(0.0055)	(0.0422)	(0.0036)	(0.0541)
(VSS_{ikt-1}) x Oil Palm	0.0274***	0.0417***	0.2123***	
	(0.0077)	(0.0086)	(0.0565)	
(VSS_{ikt-1}) x Soybeans	0.0037	0.4401		
	(0.0975)	(0.5504)		
(VSS_{ikt-1}) x Tea	-0.0471*	0.0503**	0.1222***	0.0235*
	(0.0259)	(0.0205)	(0.0249)	(0.0120)
Observations	66,692	66,692	66,692	66,692
Imp.-product-time FE		YES		
Exp.-imp.-time FE		YES		
Sample		Top producers—developing countries		

Note: Robust country-pair-product clustered standard errors are in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio, which was interacted with the exporting region and product dummies. The log of production, bilateral tariffs, and a remoteness index were included as controls but are not displayed here. The sample is restricted to exporters that are top producers from developing countries. The "other regions" group includes developing countries from regions without significant producers of the selected commodities, such as Europe and Central Asia and the Middle East and North Africa.

Further exploring the product dimension of these effects, table 5 displays the disaggregated results by VSS product for the three main exporting regions and a group of other developing regions that barely export. We estimate these effects by introducing a triple interaction between exporting region dummies, product dummies, and VSS coverage. [26] Even though this breakdown allows us to observe the heterogeneity in the effects of certifying products in each exporting region, these results should be interpreted with caution only a few observations may be available for identification for some coefficients. For instance, the only top tea producer in LAC is Argentina, and the LAC coefficient is only identified with Argentinian exports. Nevertheless, our results suggest robust trade effects for banana exports (2.1%) and palm oil exports (2.74%) in the main LAC producers.[27] Cocoa VSS certification appears to boost trade mainly for exporters from East and South Asia and the Pacific (13.4%); however, this result is not robust in the sample all developing. VSS sugarcane certification has promotes trade, especially for top producers in South and East Asia and the Pacific. Tea has a significant, positive effect on exports from Sub-Saharan Africa and South and East Asia and the Pacific.

[26] We do not include NTMs as a control in order to have more degrees of freedom in estimating each parameter. Instead, we include exporting-region-product fixed effects.

[27] Robustness was assessed by estimating the equation with NTMs and also for a larger sample of all developing countries. The results are shown in annex C, table C7. For example, the positive effect of coffee certification in LAC is not robust to changes in the specification.

5.1 Trade effects of VSS adoption across income levels: larger effects for low-income exporters and high-income importers

As noted above, the main producers of the selected commodities are developing countries, where institutions and social and environmental regulations tend to be weaker than in high-income countries (Dasgupta et al., 2001). To analyze how the different levels of development of exporters and importers might affect this relationship, we first replicate an identification strategy proposed by Bemelmans et al. (2023) for our sample.

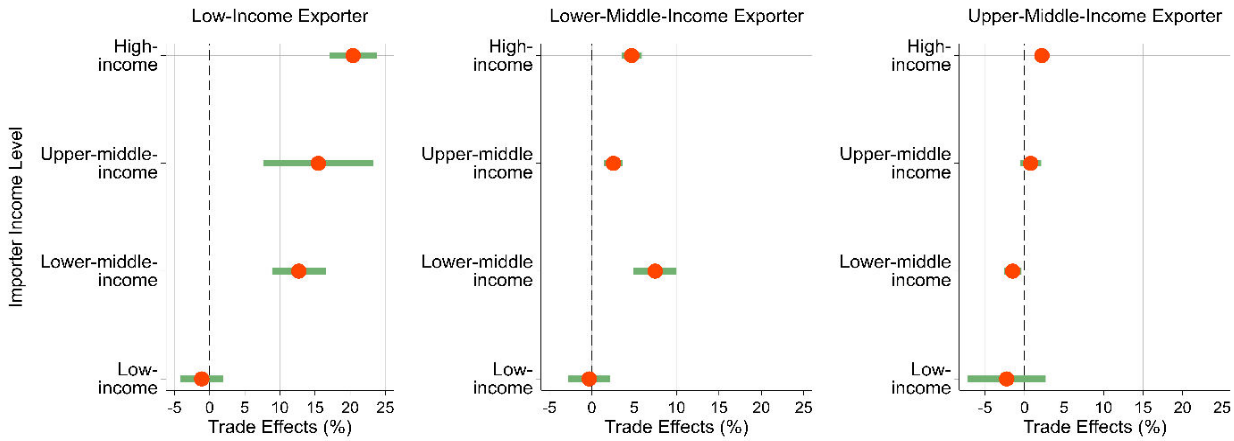
We first assess how the use of VSS schemes changes when we vary the GDP per capita of the importer or exporter (table 6, columns 1 and 2). We find that VSSs have a positive impact that decreases with the exporters' GDP per capita. In other words, the impact of VSSs on trade is larger for low-income countries, and this impact decreases as GDP per capita rises. From the importer's perspective, we observe the reverse relationship: the higher the importer's GDP per capita, the larger the trade effects associated with VSS certification. Finally, we compute a measure of institutional differences, proxied by the ratio of GDP per capita for importers and exporters. We find that the larger the gap between the development levels of importers and exporters, the larger the effect of VSSs on trade. This result supports the hypothesis that VSSs are important in bridging the institutional gap between countries at different stages of development (Goedhuys and Sleuwaegen, 2016; Bemelmans et al., 2023).

Table 6. Trade Effects of VSS Adoption; PPML by Income Level

Variables	(1) PPML	(2) PPML	(3) PPML	(4) PPML	(5) PPML	(6) PPML
$VSS_{ikt\text{-}1}$	0.0523***	-0.0143**	0.0037	0.0550***	-0.0125*	0.0033
	(0.0064)	(0.0069)	(0.0037)	(0.0049)	(0.0068)	(0.0036)
$\ln(GDP_{pc}^{origin}) \times VSS_{ikt\text{-}1}$	-0.0187***			-0.0202***		
	(0.0036)			(0.0029)		
$\ln(GDP_{pc}^{destination}) \times VSS_{ikt\text{-}1}$		0.0110***			0.0108***	
		(0.0021)			(0.0021)	
$\ln(GDP_{pc}^{difference}) \times VSS_{ikt\text{-}1}$			0.0123***			0.0128***
			(0.0016)			(0.0015)
Observations	65,612	65,710	64,639	89,581	88,454	87,208
Imp.-Product-Time FE	YES	YES	YES	YES	YES	YES
Exp.-Imp.-time FE	YES	YES	YES	YES	YES	YES
Controls	2	2	2	1	1	1

Note: Robust country-pair-product clustered standard errors are in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio. This variable is interacted with the log of GDP per capita of the exporter (column 1), the importer (column 2), and the difference between them. The log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMS are included as controls but are not displayed here. The sample is restricted to exporters that are top producers from developing countries and LAC.

Figure 5. Trade Effects of VSS Adoption; PPML by Developing Exporter and Importer Income



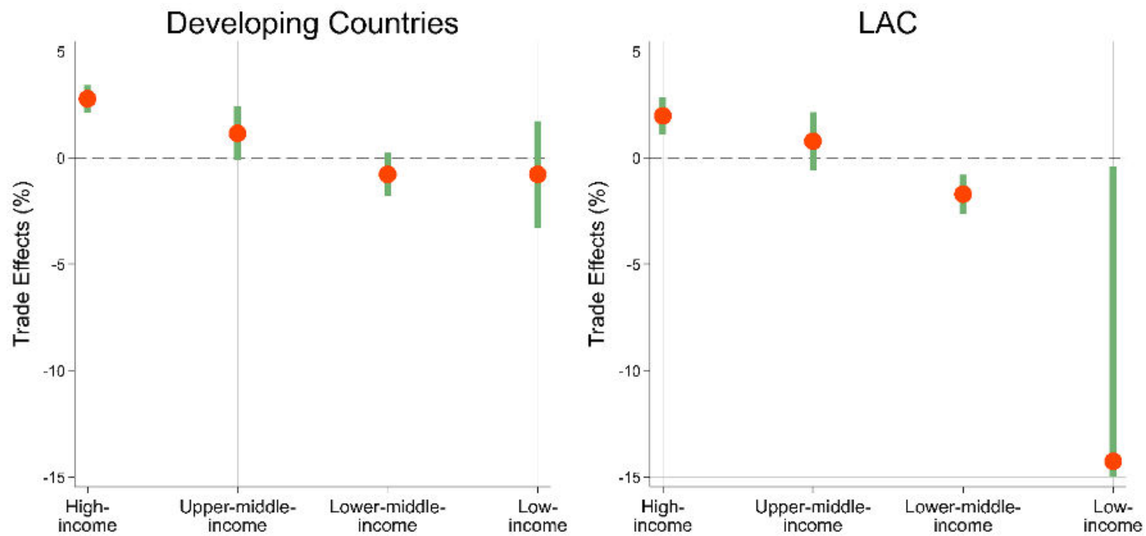
Note: The red dots and the green intervals represent the point estimate and the 95% confidence interval, respectively. The dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio. VSS coverage was interacted with exporting region and importing country income group dummies. The log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMs were included as controls but are not displayed here. The sample is restricted to exporters that are top producers from developing countries and LAC. See table C8 in annex C for the estimation results.

However, table 6 does not clearly convey the magnitude of the effect. Figure 5 shows the estimates of our baseline model with a double interaction between exporter and importer income group dummies.[28] Since we only include developing countries in our exporter group, no high-income group is defined. The results confirm what we have already identified and also give us an idea of the magnitude of this effect. When an exporter from a low-income country exports to a high-income country, each additional percentage point in its VSS coverage is likely to increase trade by 20.4%. This effect is slightly smaller for upper-middle-income and lower-middle-income importer countries (15.5% and 12.7%, respectively). In the middle and left panels, we observe that these effects are smaller for lower- and upper-middle-income exporters. For instance, when an upper-middle-income exporter increases its VSS coverage by 1 percentage point, its trade with high-income importer countries increases by 2.2%.

Figure 6 shows estimates of how the trade effects of VSS coverage vary by importer income level in developing countries, particularly in LAC. In the first panel of figure 6, we interact the VSS coverage variable with income group dummies for importers. For this developing world specification, we find that after combining all developing countries into a single basket, only exports to high-income destination markets are associated with increased trade following an increase in VSS-certified area. The impact on upper-middle-income importers is only significant at the 90% confidence interval. However, we find no evidence of a similar impact in the remaining income group classifications. When we look at the top LAC producers, an increase of 1 percentage point in the VSS coverage leads to a 2% increase in exports to high-income destinations. We also observe bilateral trade gains when trading with higher-income partners and a trade loss when trading with lower-income countries. This suggests that by increasing its share of VSS-certified land, LAC might be diverting its exports from low-income to high-income destinations.

[28] Importing countries were classified by income level according to the World Bank classification (Fantom et al. 2016).

Figure 6. Trade Effects of VSS Adoption; PPML By Importer Income; World and LAC Exporters



Note: The red dots and the green intervals represent the point estimate and the 95% confidence interval, respectively. The dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio. In the first panel, VSS coverage is interacted with importing country income group dummies. In the second panel, VSS coverage is interacted with exporting region and importing country income group dummies. The log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMS were included as controls but are not displayed here. The sample is restricted to exporters that are top producers from developing countries and LAC. The X-axis restrained to -10 for visualization purposes. See table C9 in annex C for the exact estimation results.

Furthermore, the finding that exports to higher-income destinations increase with higher VSS coverage also holds for other developing countries in South and East Asia and the Pacific. A 1-percentage-point rise in these countries' VSS coverage increases exports to high-income destinations by 5.8% and to upper-middle-income destinations by 2.8%. There is no significant impact on exports to lower-income countries. For Sub-Saharan Africa, the effect is positive for all country groups, with 3.4% effect on trade to high-income destinations (see annex C, table C9).[29]

In sum, while some of our findings are consistent with the existing literature, others diverge. First, we find that high-income importer countries are driving demand for more sustainable consumption. This is also revealed by Bemelmans et al. (2023) in their study on the VSS certification of tropical commodities and by Blyde and Ramirez (2022) in their examination of the emission intensities of Chilean exporters. Second, lower-income exporters benefit more from adopting VSSs, as observed by Andersson (2019), who found that increasing certification coverage has a greater positive effect on trade for low-income economies than for high-income ones. In addition, Fiankor et al. (2020) find that trade effects are larger for developing countries than for developed ones. In contrast, Ehrich and Mangelsdorf (2018) observed that the trade-enhancing effect of certification remains robust only for high- and middle-income economies and disappears for low-income economies.

[29] Estimates for the Sub-Saharan African group should be treated with caution, as many countries are not included due to missing data in our control NTMs. We do not show the estimates without these controls because the PPML estimator did not converge in this case.

5.2 The proliferation of standards: more choices, less trade

As described above, the number of new private standards have surged in recent decades. This prompts another empirical question: how has their proliferation impacted trade flows? More VSS options for producers can lead to more competition and a reduction in compliance costs, thereby fostering larger export flows. On the other hand, there are also reasons to believe that this proliferation might be detrimental to trade. First, the existence of too many standards might lead to a race to the bottom, where requirements are weakened to gain market share. For producers, complying with VSS requirements may entail additional costs, particularly when they must comply with multiple standards with divergent monitoring, reporting, and assurance requirements, leading to a duplication of costs. On the consumer side, more options might lead to confusion and contribute to a sense of greenwashing (Marx and Wouters, 2014; Mori Junior et al., 2016; UNFSS, 2020).

To evaluate this hypothesis, we interact our variable of interest, VSS coverage, with a count variable representing the number of different labels certifying the production of good *k* in country *i* at time *t*. To the best of our knowledge, this is the first attempt to analyze this issue empirically, and we acknowledge that we cannot capture the whole picture because we only have data on a limited sample of VSS schemes. Nevertheless, we find that the effect of certified area size remains positive for top producers but decreases with the proliferation of private standards (table 7). Thus, the more options available to producers, the smaller the trade effects of VSS adoption. Table 7, column 1 shows that a 1-percentage-point increase in VSS coverage boosts trade by 3.5%; however, the availability of each additional VSS scheme reduces this estimated effect by 0.66 percentage points. Alternating the set of controls makes this result robust (table 7, column 3). However, when we consider all small producers in developing countries, that is, those with a share of world production below 0.5%, the effect is no longer significant.

Table 7. Trade Effects of VSS Adoption When Multiple Labeling Schemes Are Available

Variables	(1) PPML	(2) PPML	(3) PPML	(4) PPML
VSS_{ikt-1}	0.0350***	0.0071	0.0375***	0.0111**
	(0.0059)	(0.0062)	(0.0057)	(0.0048)
Num. $labels_{ikt-1}$ x VSS_{ikt-1}	-0.0066***	0.0022	-0.0070***	0.0006
	(0.0018)	(0.0020)	(0.0017)	(0.0016)
Num. $labels_{ikt-1}$	0.4210***	0.3108***	0.5133***	0.3902***
	(0.0445)	(0.0424)	(0.0465)	(0.0406)
Observations	66,692	188,735	90,856	279,343
Imp.-product-time FE	YES	YES	YES	YES
Exp.-imp.-time FE	YES	YES	YES	YES
Sample	Top producers—developing countries	All developing Countries	Top producers—developing countries	All developing countries
Controls	2	2	1	1

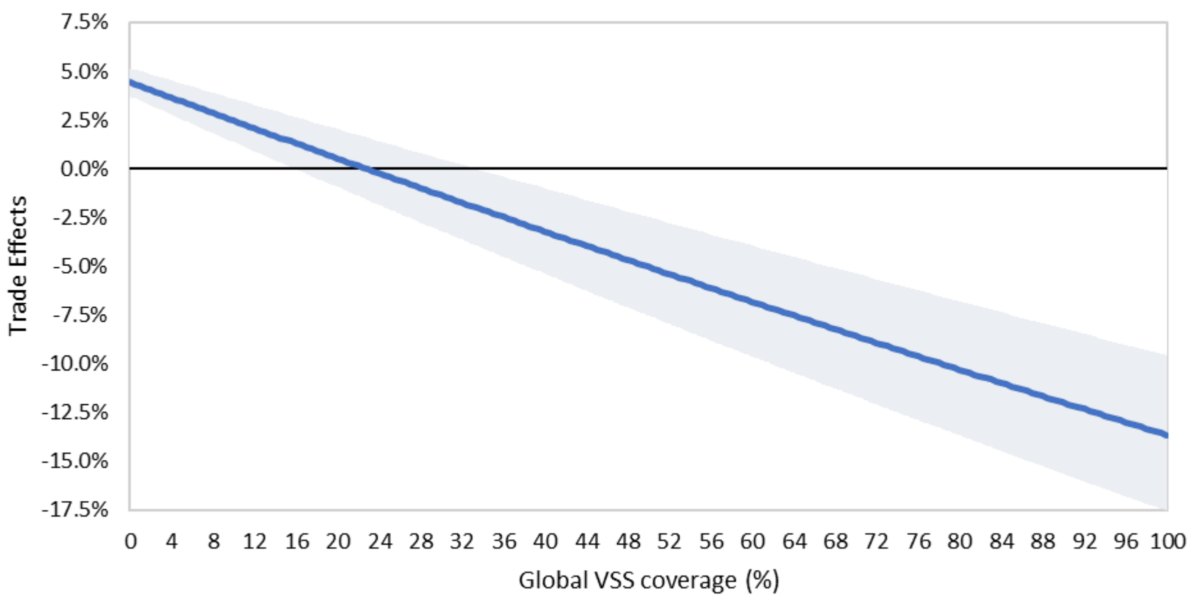
Note: Robust country-pair-product clustered standard errors are in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio. This variable is interacted with the count of VSS schemes certifying each commodity in each country and year. Control set (1) includes the ln of production, bilateral tariffs, and a remoteness index. Control set (2) also includes the prevalence score of different NTMs. The sample is restricted to exporters that are top producers from developing countries and LAC in columns 1 and 3 and includes all developing countries in columns 2 and 4.

5.3 Competition in global markets: Larger benefits for less saturated markets

In this section we explore how the relationship changes given the market's saturation. We expect that effects of VSS adoption will differ depending on the supply of VSS commodities in the global market. For this purpose, we modify our baseline estimation to allow a non-linear relationship of VSS adoption conditional on the global share of VSS.

Our results reveal a negative and significant interaction term between local VSS adoption and global VSS adoption (see Table C10 in Annex C), indicating that the positive effect of VSS adoption fades at higher levels of global VSS coverage.[30] To illustrate this point more clearly, we calculate the marginal effect of this specification.[31] Figure 7 displays the effects of increasing VSS adoption by 1 p.p. given different levels of VSS coverage.

Figure 7. Marginal effects of VSS adoption conditional on global VSS coverage



Note: The line represents the marginal effects from the model and the shaded are its respective 95% confidence interval. The dependent variable is bilateral trade in levels. The independent variable is the coverage ratio of VSS. This variable is interacted with the global coverage of VSS. As control variables we include ln of domestic production and ln of foreign production, bilateral tariffs and a remoteness index. Sample includes all developing countries and LAC.

This figure provides some interesting intuitive insights. Notably, it suggests that less saturated global markets offer greater export potential. For instance, when the global VSS coverage for a commodity is near zero, increasing local VSS coverage can lead to an export increase of approximately 4.4%. However, as more farmers certify their production, this positive effect begins to diminish and eventually turns negative. In scenarios where global VSS coverage is substantial—around 60%—further increasing domestic VSS coverage can lead to a decline in exports by about 6.8%. This phenomenon can be explained by a persistent demand for non-certified products, as VSS production typically comes with a premium price. If the majority of global production is already certified, increasing domestic coverage may come at the expense of non-

[30] We implement different robustness checks, first estimating the relationship in different subsets of the sample and changing global coverage for the coverage of the other countries. All the estimates confirm a negative significant interaction term. See table C10 in Annex C.

[31] $ME = e^{(\beta_1 + \varphi VSS_{kt-1})} - 1$, where β_1 is the parameter from domestic VSS coverage and φ is the parameter from the interaction between domestic and global VSS coverage ratios.

certified products in the market. This might lead to lower exports as part of the foreign consumers cannot pay the extra premium.

Furthermore, this average effect helps explain the observed heterogeneity in product-specific effects. Products with a larger global coverage ratio – as shown in section 3 – showed smaller or even negative trade effects.

5.4 Proximity to final consumer: VSS adoption has larger trade effects for products that are closer to consumers

The characteristics and end-use of the commodities analyzed here vary. Bananas tend to be harvested and sold almost directly to final consumers, both domestically and abroad. Cotton, on the other hand, goes through more stages of processing before reaching consumers. Following this line of reasoning, we have loosely classified the commodities analyzed in this study into two groups: "downstream" and "upstream." We consider bananas, coffee, cocoa, and tea to be downstream products and cotton, palm oil, soybeans, and sugarcane to be upstream products.[32] To better understand how this "distance" from final consumers affects the trade effects of VSS adoption, we estimate our baseline equation and interact it with upstream and downstream dummies that correspond to the classification described above.

Table 8 reports our findings. VSS adoption appears to have larger trade effects on products that tend to be closer to final consumers than products that go through more production steps before reaching these. A 1-percentage-point increase in the VSS coverage ratio of "downstream" commodities increases trade by approximately 2.3%. For more "upstream" products, this effect is smaller. Looking at the sample of all developing countries, the effect is not significant at the 5% level (table 8, columns 3 and 4). When only the top producers from developing countries are considered, there is a positive effect of around 1.6%–1.7%.[33]

Table 8. Trade Effects of VSS Adoption, By Upstream and Downstream Products

Variables	(1) PPML	(2) PPML	(3) PPML	(4) PPML
VSS_{ikt-1} x B2B	0.0166***	0.0155***	0.0065*	0.0049
	(0.0047)	(0.0048)	(0.0034)	(0.0040)
VSS_{ikt-1} x B2C	0.0228***	0.0213***	0.0226***	0.0236***
	(0.0033)	(0.0036)	(0.0026)	(0.0029)
Observations	90,856	66,692	279,343	188,735
Imp.-product-time FE	YES	YES	YES	YES
Exp.-imp.-time FE	YES	YES	YES	YES
Sample	Top producers—developing countries	Top producers—developing countries	All developing countries	All developing countries
Controls	1	2	1	2

Note: Robust country-pair-product clustered standard errors are in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio. This variable is interacted with a dummy classifying bananas, coffee, cocoa, and tea as downstream products and another one classifying cotton, palm oil, soybean, and sugarcane as upstream products. Control set (1) includes ln of production, bilateral tariffs, and a remoteness index. Control set (2) also includes the prevalence score of different NTMs. The sample is restricted to exporters that are top producers from developing countries and LAC in columns 1 to 4 and includes all developing countries in columns 5 and 6.

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[32] An indicator of the distance to final demand, or upstreamness, is usually calculated using input-output tables (IOT). However, we are not aware of any IOT that disaggregates these eight commodities and therefore we are not able to calculate commodity-specific upstreamness indicators.

[33] Given our sample size and the magnitude of the estimates, the Wald test performed on the coefficients of models 1 and 2 cannot reject their being equal. However, when we extend the sample to all developing countries (columns 3 and 4), we reject that they are statistically equal, confirming that the VSS coverage ratio has larger effects on trade in "downstream" commodities.

6. *Discussion and Policy Implications*

The evidence presented can be seen as an exploratory assessment of the trade effects of VSS. Although these tend to be positive overall, they conceal considerable heterogeneity and nuances. In this section, we turn to a normative economic analysis, discussing the more complex task of translating these results into policy action.

Our main results suggest an increase in export performance for countries that adopt VSS schemes. Moreover, the positive trade effects of VSS adoption are mainly driven by high-income importers that demand higher sustainability standards, thereby helping to reduce the institutional gap between producing and consuming countries. As part of their public policy agendas, governments could work with certification bodies to incorporate ecolabel requirements into national legislation. This would ensure that producers comply with the standards of these certifications from the outset, thus ensuring that national and exportable production is sustainable and pursues other noneconomic objectives, such as environmental protection, combating climate change, and promoting sustainability. This could make developing countries better prepared to comply with the increasingly stringent environmental regulations from developed countries, such as the European Union's Regulation on Deforestation-Free Products or the Renewable Energy Directive (RED II).

Incorporating these elements into national laws is a challenge. Deciding which requirements deliver the greatest benefits or which standards governments should endorse entails navigating a complex landscape. Such decisions should be made in alliance and cooperation with private certifiers rather than in competition with them. An outstanding example of such initiatives is the collaboration between the government of Gabon and the Forest Stewardship Council (FSC) to develop markets for sustainable wood products and provide capacity building to forest communities for sustainable forest management (Bermúdez, 2021). Gabon is making the issuance of forestry permits conditional on FSC certification to increase forestry exports and thus their contribution to GDP (UNFSS, 2020). Gabon aims to have all its forest concessions certified by 2025 (FSC, 2022). The effectiveness of this domestic scheme depends, to a large extent, on widespread international recognition of VSS certification schemes and cooperation with them. Failure to achieve such recognition may hinder the potential benefits of these schemes, as happened in the case of the Indonesian Sustainable Palm Oil (ISPO) certification introduced in 2011. The ISPO is generally deemed to have been ineffective in implementing sustainability standards, which has led to low uptake in international markets (Choiruzzad et al., 2021).

Another finding of our study is that more VSS options for producers decrease the positive trade effects that these schemes have. The potential additional cost associated with the proliferation of VSSs could be addressed through equivalence and mutual recognition agreements. One successful experience is the partnership between the Associação Brasileira dos Produtores de Algodão (Brazilian Association of Cotton Producers, ABRAPA) and BCI. After a thorough benchmarking process, ABRAPA aligned its own sustainable cotton program, the Algodão Brasileiro Responsável (Responsible Brazilian Cotton, ABR) with the Better Cotton Standard. This means that cotton farmers who grow cotton in compliance with the ABR program can sell their cotton under the BCI label (BCI, 2020). However, such collaboration is rare: Marx and Wouters (2014) found that mutual recognition among VSSs is very low.

Another path could be to push for coordination and the establishment of best practices through umbrella organizations, also known as metaregulators. These organizations set the rules of the game and establish the minimum requirements that VSSs should comply with (Marx and Wouters, 2014). By establishing certain minimum requirements, the duplication of compliance costs associated with many standards could be reduced. One example is the International Social and Environmental Accreditation and Labelling (ISEAL) Alliance, which has 45 certifying labels as members, including the eight standards analyzed here. ISEAL's members are required to meet accepted international best practices, with the aim of distinguishing legitimate VSSs from less credible schemes (Loconto and Fouilleux, 2014).

Trade policy and the architecture of trade institutions could also play an important role. Collaborative efforts to identify which standards and criteria to promote could be undertaken at the bilateral, preferential, and, ideally, multilateral levels. Many countries are turning to trade agreements to achieve objectives beyond the purely commercial, such as addressing social and environmental issues. According to the UNFSS (2020), 19 FTAs refer to VSSs or related terms like "ecolabeling," "sustainability standards," or "certifications" to promote objectives related to environmental and social provisions. However, most of these are between developed countries, not developing countries (Bermúdez, 2021). Although some of these agreements refer to the inclusion of VSS-certified products, quantifiable commitments are not clearly established. This suggests that there is scope for VSS-certified products to be included in trade agreements, but much more work is needed to turn these VSS-related requirements into legally binding requirements.

The costs associated with VSS certification vary. Using trade policy to reduce trade costs associated with tariffs and NTMs could be one way to compensate exporters for these costs. This could further increase the impact of certifications on trade, as discussed in previous sections. Marx (2018) discusses three options for implementation in a unilateral setting from the perspective of the European Union. The first option is to make duty-free access conditional upon certification. The second option is to grant tariff preferences to certified products. The third, more feasible option would be to integrate the VSS into the reporting mechanisms of the Generalized System of Preferences (GSP). This could be implemented by either relying on the information provided by the VSS or by assessing the adoption of the VSS in GSP countries as part of the periodic evaluation of the GSP through a scorecard or roadmap, thus encouraging governments to promote and provide incentives for adopting VSSs. Such proposals could be extended to bilateral trade agreements, as implemented in the Indonesia–EFTA trade agreement, which grants lower tariffs for some specific commodities such as palm oil when they are certified (UNCTAD, 2021). Along the same lines, a similar proposal could be further explored to recognize these private standards as equivalent to certain mandatory technical measures so that the producer does not have to incur compliance costs twice.

Collaboration between governments and businesses is critical to overcoming the challenges associated with the adoption of certification and subsequent participation in international trade. With government support, business participation can be increased through incentive programs that reduce the cost of obtaining certification by offering extended payment terms and flexible payment options. Another strategy is to establish public certification to include marginalized producers (Clark and Martínez, 2016).

7. *Conclusions*

This paper analyzes how changes in the share of VSS-certified land affect international trade flows in eight agricultural commodities. The theory suggests that private standards can impact trade in either direction, either boosting or reducing flows. Using a new, more comprehensive data set than previous studies, we shed light on this empirical question by letting the data reveal the dominant force. Our analysis goes beyond the existing literature by examining more commodities, more certifications, and more years, with a particular focus on developing countries. This is justified given the central role of agricultural commodities in their economies relative to developed countries. We also highlight how these effects vary across regions, with a particular focus on Latin America and the Caribbean.

The results indicate that increasing the share of VSS-certified land in a country's total harvested area increases overall exports. This positive, statistically significant relationship is consistent with previous literature (Bemelmans et al., 2023; Fiankor et al., 2020) and is robust to different specifications and models (OLS and IV-OLS). On average, a 1-percentage-point increase in the share of certified land in production increases the value of exports by 1.86%. We also identify significant non-linear effects, leading to lower trade effects as certification coverage levels increase.

To better understand this relationship, we decompose this aggregate effect across the export, import, and product dimensions. We find that bananas, palm oil, tea, and cotton drive the trade-enhancing effects of increased VSS certification. On the other hand, increasing the VSS coverage of sugarcane, cocoa, coffee, and soybean production did not lead to robust changes in trade. Looking at regional differences, we observe several heterogeneities in the results. In Latin America and the Caribbean, the effect is positive for bananas and palm oil. For tea, the positive effects come mainly from Asia and Africa.

Another interesting aspect observed in our study is that the trade effects of VSS adoption are larger when the exporter is from a low-income country and the destination market (importer) is a high-income country. This effect also holds for LAC countries. Moreover, we find evidence that the effect is negative for LAC exports to low-income countries. These results suggest a shift in export destinations, with increased production under VSS schemes leading to an increase in exports to high-income countries and a decrease in exports to low-income countries (Ehrich and Mangelsdorf, 2018). Furthermore, our results show that VSSs have a greater impact on trade when exporters' and importers' development levels are more disparate. This suggests that VSSs play a crucial role in bridging the institutional gaps that may exist between countries at different stages of development (Goedhuys and Sleuwaegen, 2016; Bemelmans et al., 2023).

Our analysis also provides some other insights into the interaction between VSS certification and export performance. First, it shows that the impact of VSS adoption remains positive for the main producers in developing countries but declines as private standards proliferate. This suggests that as producers' options expand, the trade effects of VSS adoption become less pronounced. Second, there appear to be additional gains associated with early adopters of VSS. In less VSS saturated global markets — characterized by low global VSS coverage — increasing the domestic VSS coverage generates larger export gains. Third, when we split the analyzed commodities according to their proximity to the final consumer, we observe that the effect is larger for commodities that are "closer" to consumers than for the commodities that usually undergo more steps of production until they reach their final demand.

In summary, by exploring the macro effects of VSS schemes, we find that they appear to be a good signaling tool for consumers in developed countries. Such initiatives boost the demand for commodities produced in developing countries, leading to higher exports for these countries. However, these aggregate effects may still mask considerable heterogeneity at a more granular level. Micro- and country-level studies are needed to complement this research and better understand the nuances of this relationship. For example, some features of VSS may be beneficial for trade, while others may be detrimental. Moreover, economies of scale may play a role, and the impact of VSS schemes may vary depending on who adopts them, such as large or small producers. These varied impacts highlight the need for a closer examination of the specific effects of VSSs on different parties. In addition, studying how different policies affect this relationship is crucial for informing effective policymaking.

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Technical Appendices

A. Data sources and processing

Data was gathered from several sources. The value and volume of **trade flows** come from BACI (Gaulier and Zignago, 2010). The following 6-digit harmonized system (HS) codes were used to identify the commodities included in this study.

Table A1. HS 6-Digit Codes and Descriptions

Commodity	HS 6-digit code	Description
Banana	080300	Fruit, edible; bananas (including plantains), fresh or dried
Sugarcane	121299	Vegetable products (including unroasted chicory roots, *Chicorium intybus* sativum variety); n.e.c. in chapter 12, fresh, chilled, frozen or dried, ground or unground, primarily for human consumption
	170111	Sugars; cane sugar, raw, in solid form, not containing added flavouring or colouring matter
	170112	Sugars; cane sugar, raw, in solid form, not containing added flavouring or colouring matter
Cocoa	180100	Cocoa beans; whole or broken, raw or roasted
	180310	Cocoa; paste, not defatted
	180320	Cocoa; paste, wholly or partly defatted
	180400	Cocoa; butter, fat, and oil
	180500	Cocoa; powder, not containing added sugar or other sweetening matter
Coffee	090111	Coffee; not roasted or decaffeinated
	090112	Coffee; decaffeinated, not roasted
	090121	Coffee; roasted, not decaffeinated
	090122	Coffee; roasted, decaffeinated
Cotton	120720	Oil seeds; cotton seeds, whether or not broken
	520100	Cotton; not carded or combed
Palm oil	151110	Vegetable oils; palm oil and its fractions, crude, not chemically modified
	151190	Vegetable oils; palm oil and its fractions, other than crude, whether or not refined, but not chemically modified
Soybeans	120100	Soya beans; whether or not broken
Tea	090210	Tea, green; (not fermented), in immediate packings of a content not exceeding 3kg
	090220	Tea, green; (not fermented), in immediate packings of a content exceeding 3kg
	090230	Tea, black; (fermented) and partly fermented tea, in immediate packings of a content not exceeding 3kg
	090240	Tea, black; (fermented) and partly fermented tea, in immediate packings of a content exceeding 3kg

The **VSS data** was provided by the FiBL and the ITC. We obtained information on VSS harvested area and production in tons from 2009 to 2021. The data before 2012 contained many missing observations and was not properly disaggregated into countries, therefore we initiate our analysis using data from 2012 onwards. Even in the period post-2012 there is an issue that for some VSS labels, countries, and commodities only aggregated numbers are reported by the VSS's, due to confidentiality issues. This can sometimes change from year to year when the numbers of partners/producers are going below a certain threshold. Two strategies were implemented to deal with this issue. First, by assuming a minimum VSS coverage ratio, if a country has a missing in one label and a positive value in another label, the coverage ratio will not be missing. Second, these missing values were more frequent in countries with a smaller number of producers/harvested area. By performing our main estimations in a sample with main producers, many of the countries with missing are not considered in the estimation sample. This segmentation of the data facilitated the reduction of the number of missing values as shown in the table below:

Table A2. Missing Values According to the Different Samples

Year	Missing	Total	Percent missing	Missing	Total	Percent missing	Missing	Total	Percent missing
Sample	All producers			Developing countries			LAC countries		
2009	623	777	80.18	501	620	80.81	188	249	75.50
2010	609	777	78.38	488	620	78.71	187	249	75.10
2011	483	777	62.16	380	620	61.29	130	249	52.21
2012	404	777	51.99	309	620	49.84	104	249	41.77
2013	340	777	43.76	247	620	39.84	84	249	33.73
2014	319	777	41.06	227	620	36.61	79	249	31.73
2015	331	777	42.60	236	620	38.06	95	249	38.15
2016	305	777	39.25	220	620	35.48	90	249	36.14
2017	271	777	34.88	169	620	27.26	70	249	28.11
2018	314	777	40.41	219	620	35.32	80	249	32.13
2019	311	777	40.03	218	620	35.16	80	249	32.13
2020	315	777	40.54	219	620	35.32	81	249	32.53
2021	279	777	35.91	201	620	32.42	72	249	28.92

The statistics on **domestic production and harvested area** were gathered from FAO. Using these datasets, the minimum VSS coverage for each producer, product, and year was calculated as follows:

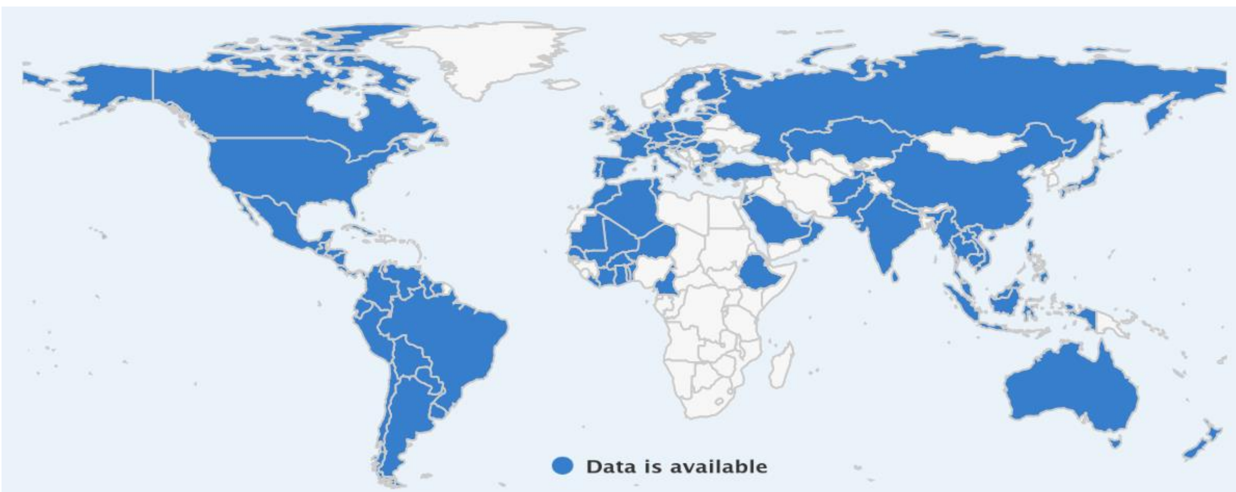
$$VSS_{ikt} = \frac{\max_{l}\left(area_{ikt}^{1}, area_{ikt}^{2}, \dots, area_{ikt}^{L}\right)}{Y_{ikt}}$$

The **tariff data** comes from the World Bank's World Integrated Trade Solution (WITS). Due to the well-documented problems with this dataset (Teti, 2023), we downloaded the bulk files for most-favored nation (MFN), ad valorem equivalents (AVE) MFN, preferential, and AVE preferential and performed some data cleaning. Since many country-year tariffs were missing, we performed the following steps to assemble a complete tariff series in a panel format. First, we filtered for the HS codes for the commodities included in this study and converted them to the HS 2007 version. Second, we considered the AVE tariffs for preferential and MFN tariffs whenever they were missing. Third, whenever a bulk file was missing, we used the tariff for the previous year. For preferential tariffs, we included an additional step: we merged the data with the regional trade agreement (RTA) dataset and substituted the preferential tariffs only if an RTA was binding in that particular year. Fourth, if a complete series for MFN and preferential tariffs was available, we took the lowest value to construct our applied tariff series. Last, whenever a commodity was linked to more than one HS code, we averaged the bilateral tariffs using a simple average.

The data on **nontariff measures (NTMs)** comes from TRAINS—UNCTAD. We calculate the prevalence scores of NTMs following Rial (2020). The prevalence scores were computed at the HS 6-digit product level and aggregated as a simple average for each commodity. We calculated three types of NTM variables and considered all types of measures, from technical regulations to more coercive (nontechnical) trade control measures. First, nontariff import-related measures imposed by country *j* on exporting country *I*, such as a testing requirement for banana imports from a disease-affected country. Second, nontariff export-related measures imposed by country *i* on importing country *j*, which could be any export control imposed on a particular importing partner. Finally, nontariff export-related measures imposed by country *i* on the world, which could be any export registration requirements for technical reasons. Nontariff import-related measures imposed by the importing country on the world were not calculated because they wer e already accounted for in the importer-product-time fixed effects.

We performed two main data management steps to transform the data into a panel. First, we transform the data into a panel by assuming that whenever a year was missing, the rules and legislation from the previous period were binding. When there were missing observations at the beginning of the data, we assumed that the data from the first year in the panel was binding for the initial years. Second, we made a small adjustment to the multilateral measures (i.e., those affecting all partners). In the data, “the world” was shown as the affected economy. However, a few measures were listed that affected almost all individual countries. Thus, whenever a measure affected more than 150 economies, it was considered to be a multilateral measure rather than multiple bilateral measures. Last, for countries with no data available for 2010 to 2021, we treated the data as missing. This mainly concerned Africa and the Middle East (see figure A1). Among LAC countries, a few Caribbean nations were left out, such as the Dominican Republic and Haiti. Whenever a country was present in the dataset but reported no NTM, we considered the prevalence score to be zero.

Figure A1. Availability of NTM Data



Source: TRAINS—UNCTAD.

Additional data on RTAs comes from Mario Larch’s Regional Trade Agreements Database in Egger and Larch (2008). Gravity variables such as distance and importer and exporter GDP per capita were retrieved from the CEPII gravity database in Conte et al. (2022).

B. Descriptive data

Table B1. Main Producers of Bananas, 2013–2021

Rank	Country	Production (millions of tons)	Share of global production	Harvested area (millions of hectares)	Share of global harvested area	Trade (millions of USD)	Share of global trade	Trade rank
1	IND	273	19.4%	8	8%	621	0.5%	22
2	CHN	103	7.3%	3	3%	327	0.3%	34
3	PHL	81	5.8%	4	4%	16507	13.5%	2
4	IDN	68	4.8%	1	1%	92	0.1%	55
5	ECU	65	4.6%	3	3%	30361	24.8%	1
6	BRA	61	4.3%	4	4%	291	0.2%	36
7	UGA	57	4.1%	13	12%	50	0.0%	63
8	COD	50	3.6%	11	11%	0	0.0%	123
9	CMR	49	3.4%	4	4%	1503	1.2%	17
10	COL	44	3.1%	4	4%	9672	7.9%	5
11	GHA	39	2.8%	4	3%	449	0.4%	26
12	GTM	38	2.7%	1	1%	9889	8.1%	4
13	NGA	35	2.5%	4	4%	0	0.0%	124
14	AGO	34	2.4%	1	1%	21	0.0%	71
15	TZA	34	2.4%	6	6%	7	0.0%	84
16	RWA	24	1.7%	4	4%	1	0.0%	108
17	CRI	23	1.7%	1	0%	13147	10.7%	3
18	MEX	21	1.5%	1	1%	2627	2.1%	8
19	CIV	21	1.5%	4	4%	2468	2.0%	12
20	DOM	20	1.4%	1	1%	3473	2.8%	7
21	PER	20	1.4%	2	1%	1525	1.2%	16
22	VNM	19	1.3%	1	1%	719	0.6%	21
23	KEN	14	1.0%	1	1%	1	0.0%	115
24	BDI	12	0.9%	2	2%	1	0.0%	106
25	EGY	11	0.8%	0	0%	62	0.1%	61
26	PNG	11	0.8%	1	1%	0	0.0%	197
27	THA	11	0.8%	0	0%	252	0.2%	39
28	MMR	11	0.8%	1	1%	192	0.2%	42
29	VEN	11	0.8%	1	1%	4	0.0%	91
30	BGD	9	0.6%	1	1%	8	0.0%	80
31	SDN	8	0.6%	0	0%	64	0.1%	60
32	CUB	8	0.6%	1	1%	0	0.0%	151
33	MWI	7	0.5%	0	0%	0	0.0%	156
		1292	**91.7%**	**91**	**90%**	**94335**	**77.1%**	

Source: FAO and BACI. Note: The main producers were selected based on those representing more than 0.5% of global production in 2013–2021. LAC countries are highlighted in light gray.

Table B2. Main Producers of Sugarcane, 2013–2021

Rank	Country	Production (millions of tons)	Share of global production	Harvested area (millions of hectares)	Share of global harvested area	Trade (millions of USD)	Share of global trade	Trade rank
1	BRA	6755	39.7%	91	38%	68931	47.1%	1
2	IND	3271	19.2%	44	18%	4338	3.0%	5
3	CHN	1001	5.9%	13	6%	3500	2.4%	7
4	THA	893	5.3%	14	6%	13068	8.9%	2
5	PAK	658	3.9%	11	4%	217	0.1%	48
6	MEX	512	3.0%	7	3%	4120	2.8%	6
7	COL	305	1.8%	4	2%	988	0.7%	16
8	AUS*	288	1.7%	4	1%	11001	7.5%	3
9	USA*	267	1.6%	3	1%	263	0.2%	44
10	GTM	264	1.6%	2	1%	5216	3.6%	4
11	IDN	259	1.5%	4	2%	104	0.1%	61
12	PHL	220	1.3%	4	2%	729	0.5%	23
13	ARG	171	1.0%	4	2%	536	0.4%	34
14	ZAF	159	0.9%	2	1%	2293	1.6%	10
15	VNM	149	0.9%	2	1%	98	0.1%	62
16	CUB	145	0.9%	4	2%	2754	1.9%	9
17	EGY	142	0.8%	1	1%	408	0.3%	37
18	MMR	99	0.6%	2	1%	866	0.6%	18
19	PER	93	0.5%	1	0%	322	0.2%	41
		15649	**92.0%**	**216**	**91%**	**119755**	**81.7%**	

Source: FAO and BACI. Note: The main producers were selected based on those representing more than 0.5% of global production in 2013–2021. LAC countries are highlighted in light gray.

Table B3. Main Producers of Cocoa, 2013–2021

Rank	Country	Production (millions of tons)	Share of global production	Harvested area (millions of hectares)	Share of global harvested area	Trade (millions of USD)	Share of global trade	Trade rank
1	CIV	17	37.3%	33	33%	46453	24.2%	1
2	GHA	8	17.1%	15	15%	24541	12.8%	3
3	IDN	6	13.3%	15	15%	11413	5.9%	4
4	CMR	3	5.8%	6	6%	6199	3.2%	10
5	NGA	3	5.8%	9	9%	6739	3.5%	9
6	BRA	2	5.0%	6	6%	2155	1.1%	16
7	ECU	2	4.3%	4	4%	7045	3.7%	7
8	PER	1	2.3%	1	1%	2181	1.1%	15
9	DOM	1	1.5%	1	1%	1957	1.0%	17
10	COL	1	1.3%	1	1%	517	0.3%	28
11	PNG	0	0.7%	1	1%	934	0.5%	21
12	UGA	0	0.6%	1	1%	670	0.3%	24
13	MEX	0	0.6%	1	1%	314	0.2%	34
14	VEN	0	0.5%	1	1%	297	0.2%	37
15	SLE	0	0.5%	1	1%	335	0.2%	31
		45	**96.8%**	**96**	**96%**	**111749**	**58.1%**	

Source: FAO and BACI. Note: The main producers were selected based on those representing more than 0.5% of global production in 2013–2021. LAC countries are highlighted in light gray.

Table B4. Main Producers of Coffee, 2013–2021

Rank	Country	Production (millions of tons)	Share of global production	Harvested area (millions of hectares)	Share of global harvested area	Trade (millions of USD)	Share of global trade	Trade rank
1	BRA	27	31.2%	17	17%	48386	17.3%	1
2	VNM	14	16.1%	6	5%	25828	9.2%	2
3	COL	7	8.0%	7	7%	23549	8.4%	3
4	IDN	6	7.3%	11	11%	9900	3.5%	7
5	ETH	4	4.9%	6	6%	7591	2.7%	10
6	HND	3	3.9%	3	3%	9646	3.4%	8
7	IND	3	3.3%	4	4%	5409	1.9%	15
8	PER	3	3.2%	4	4%	6612	2.4%	13
9	UGA	3	3.0%	5	5%	4274	1.5%	18
10	GTM	2	2.4%	3	3%	7117	2.5%	11
11	MEX	2	1.8%	6	6%	3689	1.3%	20
12	LAO	1	1.5%	1	1%	899	0.3%	34
13	NIC	1	1.3%	1	1%	4162	1.5%	19
14	CHN	1	1.2%	0	0%	2110	0.8%	26
15	CAF	1	1.0%	3	3%	4	0.0%	118
16	GIN	1	1.0%	2	2%	114	0.0%	68
17	CIV	1	1.0%	7	7%	1200	0.4%	33
18	CRI	1	0.9%	1	1%	3470	1.2%	21
19	PHL	1	0.7%	1	1%	10	0.0%	108
20	TZA	1	0.6%	2	2%	1468	0.5%	28
21	VEN	0	0.6%	1	1%	29	0.0%	92
22	MDG	0	0.5%	1	1%	64	0.0%	76
23	PNG	0	0.5%	0	0%	1366	0.5%	29
		84	**95.7%**	**92**	**91%**	**166898**	**59.6%**	

Source: FAO and BACI. Note: The main producers were selected based on those representing more than 0.5% of global production in 2013–2021. LAC countries are highlighted in light gray.

Table B5. Main Producers of Cotton, 2013–2021

Rank	Country	Production (millions of tons)	Share of global production	Harvested area (millions of hectares)	Share of global harvested area	Trade (millions of USD)	Share of global trade	Trade rank
1	CHN	261	25.1%	34	11%	403	0.3%	31
2	IND	258	24.8%	112	38%	19116	13.2%	2
3	USA*	135	13.0%	35	12%	49532	34.3%	1
4	PAK	76	7.3%	23	8%	736	0.5%	23
5	BRA	71	6.8%	11	4%	17526	12.1%	3
6	UZB	42	4.1%	11	4%	3453	2.4%	7
7	TUR	32	3.1%	4	1%	1991	1.4%	10
8	AUS*	24	2.3%	3	1%	12482	8.6%	4
9	TKM	12	1.2%	5	2%	1832	1.3%	11
10	ARG	11	1.1%	3	1%	977	0.7%	17
11	MEX	11	1.1%	2	1%	931	0.6%	19
12	BFA	11	1.0%	6	2%	4768	3.3%	6
13	GRC	10	1.0%	2	1%	5713	4.0%	5
14	MLI	8	0.8%	5	2%	1700	1.2%	12
15	BEN	8	0.8%	5	2%	3418	2.4%	8
16	CIV	6	0.6%	4	1%	2724	1.9%	9
17	CMR	6	0.6%	2	1%	1272	0.9%	14
18	MMR	5	0.5%	2	1%	105	0.1%	46
		986	**94.9%**	**266**	**91%**	**128679**	**89.1%**	

Source: FAO and BACI. Note: The main producers were selected based on those representing more than 0.5% of global production in 2013–2021. LAC countries are highlighted in light gray. Developed countries are identified with an asterisk.

Table B6. Main Producers of Palm Oil, 2013–2021

Rank	Country	Production (millions of tons)	Share of global production	Harvested area (millions of hectares)	Share of global harvested area	Trade (millions of USD)	Share of global trade	Trade rank
1	IDN	2322	58.0%	115	50%	163914	50.8%	1
2	MYS	1035	25.9%	46	20%	102966	31.9%	2
3	THA	149	3.7%	7	3%	2239	0.7%	10
4	NGA	95	2.4%	32	14%	58	0.0%	57
5	COL	75	1.9%	4	2%	2976	0.9%	8
6	ECU	31	0.8%	2	1%	1712	0.5%	11
7	PNG	29	0.7%	2	1%	4176	1.3%	4
8	GTM	28	0.7%	1	1%	3780	1.2%	5
9	HND	25	0.6%	2	1%	2638	0.8%	9
10	CMR	24	0.6%	2	1%	35	0.0%	65
11	GHA	24	0.6%	3	1%	729	0.2%	19
12	CIV	24	0.6%	3	1%	1645	0.5%	12
13	BRA	22	0.5%	1	1%	390	0.1%	29
14	COD	20	0.5%	3	1%	50	0.0%	60
		3903	**97.5%**	**222**	**96%**	**287308**	**89.0%**	

Source: FAO and BACI. Note: The main producers were selected based on those representing more than 0.5% of global production in 2013–2021. LAC countries are highlighted in light gray.

Table B7. Main Producers of Soybeans, 2013–2021

Rank	Country	Production (millions of tons)	Share of global production	Harvested area (millions of hectares)	Share of global harvested area	Trade (millions of USD)	Share of global trade	Trade rank
1	USA*	996	33.1%	301	27%	201993	37.0%	2
2	BRA	966	32.1%	304	28%	242899	44.5%	1
3	ARG	466	15.5%	161	15%	28245	5.2%	3
4	CHN	134	4.4%	71	6%	1292	0.2%	11
5	IND	105	3.5%	103	9%	1095	0.2%	12
6	PRY	89	2.9%	31	3%	19326	3.5%	4
7	CAN*	58	1.9%	20	2%	17888	3.3%	5
8	UKR	33	1.1%	15	1%	8007	1.5%	6
9	RUS	31	1.0%	21	2%	1940	0.4%	10
10	BOL	27	0.9%	12	1%	504	0.1%	17
11	URY*	22	0.7%	10	1%	5399	1.0%	8
		2927	**97.2%**	**1051**	**95%**	**528588**	**96.8%**	

Source: FAO and BACI. Note: The main producers were selected based on those representing more than 0.5% of global production in 2013–2021. LAC countries are highlighted in light gray. Developed countries are identified with an asterisk.

Table B8. Main Producers of Tea, 2013–2021

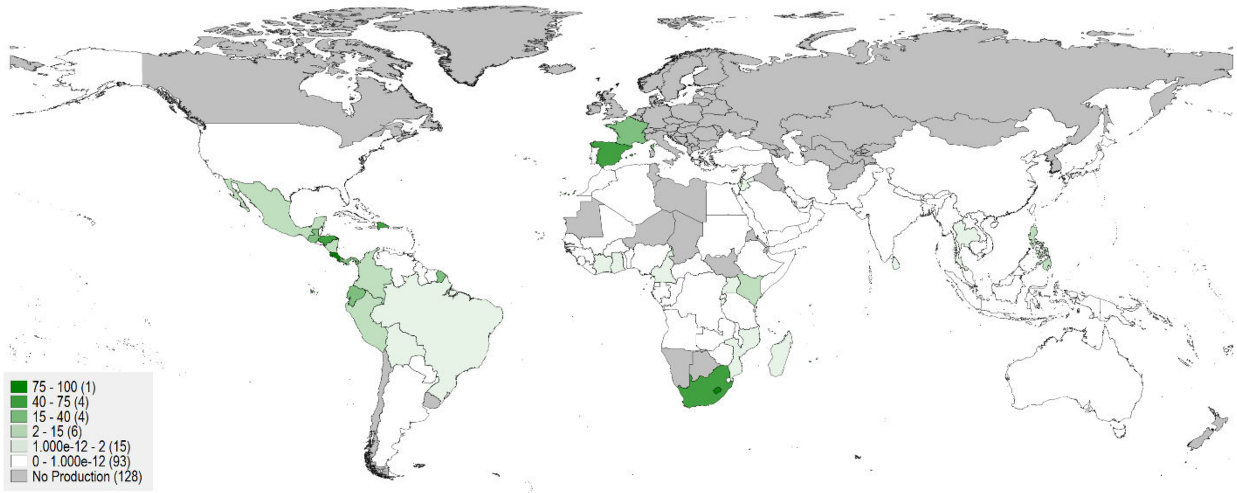
Rank	Country	Production (millions of tons)	Share of global production	Harvested area (millions of hectares)	Share of global harvested area	Trade (millions of USD)	Share of global trade	Trade rank
1	CHN	101	43.0%	24	59%	11881	18.3%	1
2	IND	50	21.4%	5	13%	6942	10.7%	4
3	KEN	20	8.4%	2	5%	11399	17.6%	2
4	LKA	15	6.3%	2	5%	10439	16.1%	3
5	TUR	12	5.2%	1	2%	157	0.2%	35
6	VNM	9	4.0%	1	3%	1619	2.5%	8
7	IDN	6	2.4%	1	3%	1227	1.9%	10
8	ARG	3	1.4%	0	1%	883	1.4%	13
9	JPN*	3	1.4%	0	1%	1166	1.8%	11
10	BGD	3	1.3%	1	1%	30	0.0%	59
11	UGA	3	1.1%	0	1%	471	0.7%	19
12	MWI	2	0.8%	0	0%	740	1.1%	15
13	TZA	1	0.5%	0	0%	400	0.6%	21
		228	**97.1%**	**38**	**94%**	**47354**	**73.0%**	

Source: FAO and BACI. Note: The main producers were selected based on those representing more than 0.5% of global production in 2013–2021. LAC countries are highlighted in light gray. Developed countries are identified with an asterisk.

Table B9. Distribution of Sample Variables

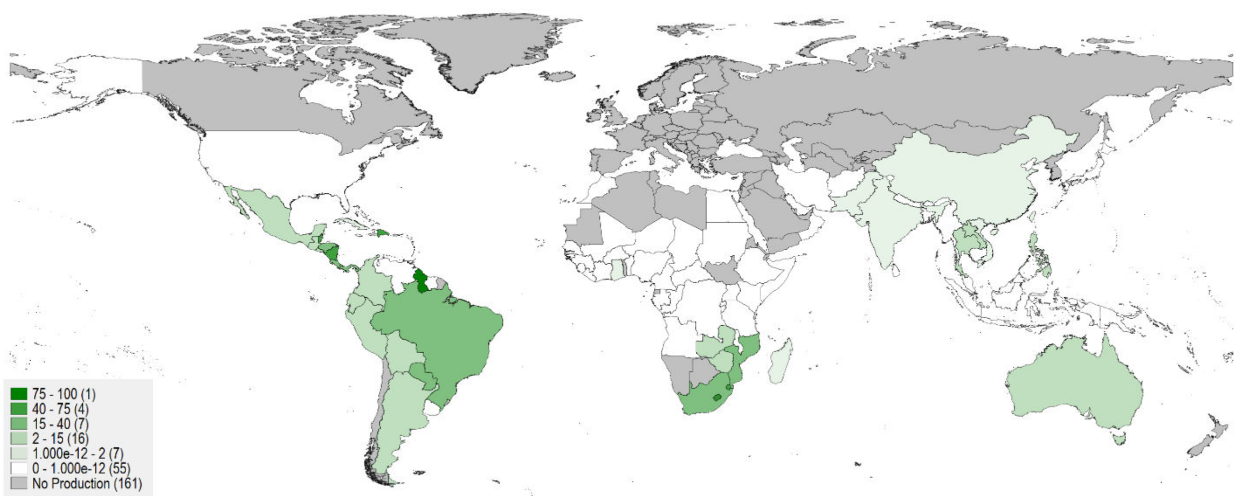
Variables	Obs.	Mean	St. Dev.	Min	Max	Obs.	Mean	St. Dev.	Min	Max
Share minimum certified area (lag. %)	5.548	8.82	21.33	0.00	100.00	1.242	14.14	22.53	0.00	100.00
Exporter area (millions of ha)	5.548	0.40	2.32	0.00	39.13	1.242	1.37	3.81	0.00	39.13
Exporter Production (millions of tons)	5.548	4.84	36.80	0.00	768.59	1.242	18.79	75.45	0.01	768.59
Export value (millions of USD)	1.054.192	1.49	75.05	0.00	27536.30	235.989	5.01	137.47	0	27.536,30
Export quantity (millions)	1.054.192	0.00	0.18	0.00	68.55	235.989	0.01	0.33	0.00	68.55
Export price (price)	123.434	0.01	0.09	0.00	18.36	61.240	0.01	0.05	0.00	5.22
Tariffs	1.054.192	0.10	0.20	0.00	4.87	235.989	0.11	0.19	0.00	4.87
NTM—exports—world	731.880	4.30	4.69	0.00	34.00	196.650	5.47	5.53	0.00	34.00
NTM—exports—bilateral	731.880	0.01	0.21	0.00	6.00	196.650	0.02	0.22	0.00	6.00
NTM—imports—bilateral	711.840	0.04	0.37	0.00	30.00	159.183	0.05	0.39	0.00	12.00
GDP per capita—origin	1.012.552	6.89	10.86	0.22	135.68	227.627	4.60	3.74	0.22	18.70
GDP per capita—destination	1.005.074	14.93	20.94	0.22	135.68	224.991	14.94	20.95	0.22	135.68
GDP per capita—difference	965.930	-8.05	23.62	-135.45	135.45	217.109	-10.36	21.30	-135.45	18.47
Remoteness (in ln)	1.054.192	31.96	2.48	25.98	36.37	235.989	31.49	2.50	26.11	36.29
Number of labels	5.548	0.72	1.15	0.00	5.00	1.242	1.87	1.58	0.00	5.00
Commodities (0/1)										
Banana	1.054.192	0.20		0.00	1.00	235.989	0.24		0.00	1.00
Sugarcane	1.054.192	0.15		0.00	1.00	235.989	0.12		0.00	1.00
Cocoa	1.054.192	0.09		0.00	1.00	235.989	0.11		0.00	1.00
Coffee	1.054.192	0.12		0.00	1.00	235.989	0.17		0.00	1.00
Cotton	1.054.192	0.14		0.00	1.00	235.989	0.11		0.00	1.00
Palm oil	1.054.192	0.07		0.00	1.00	235.989	0.10		0.00	1.00
Soybeans	1.054.192	0.16		0.00	1.00	235.989	0.07		0.00	1.00
Tea	1.054.192	0.08		0.00	1.00	235.989	0.09		0.00	1.00
Sample	All producers					Top producers—dev. countries (all LAC)				

Figure B1. Bananas: VSS Coverage (% of VSS-certified area of total harvested area), 2021



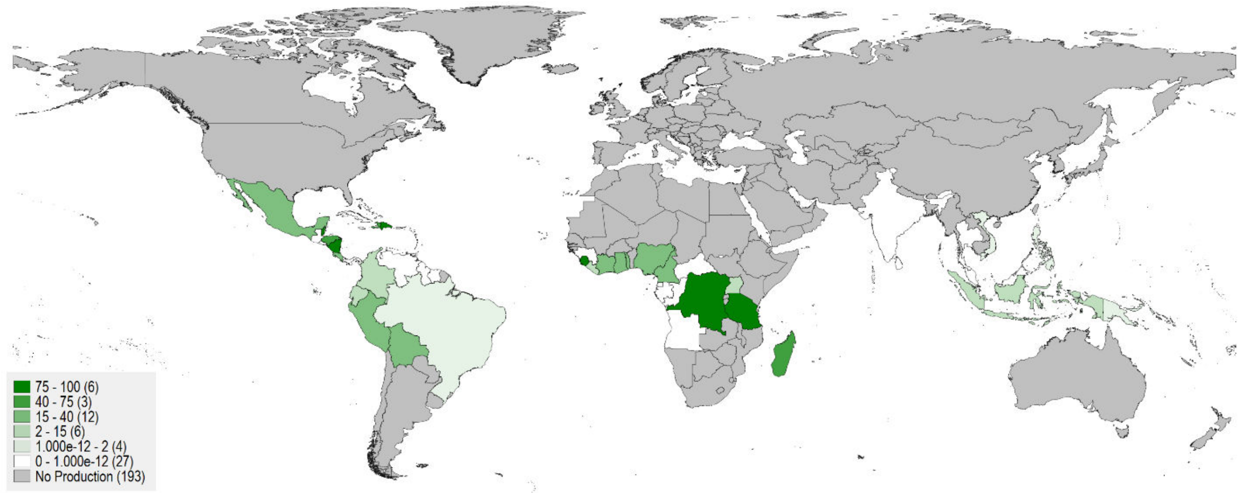
Source: Data from FiBL and the ITC. Note: This figure considers the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year). The number in parentheses represents the number of countries in each bin.

Figure B2. Sugarcane: VSS Coverage (% of VSS-certified area of total harvested area), 2021



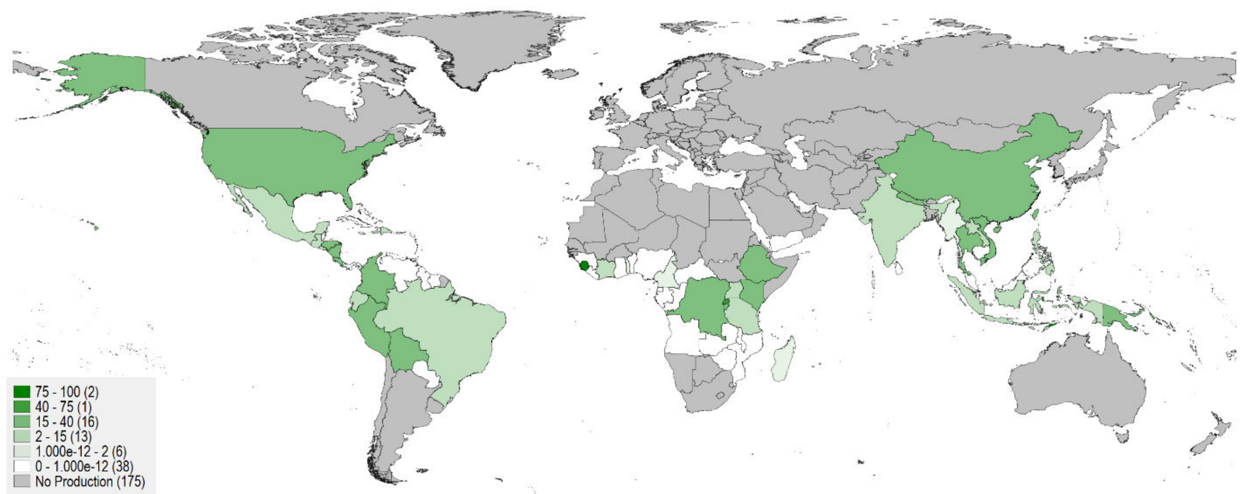
Source: Data from FiBL and the ITC. Note: This figure considers the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year). The number in parentheses represents the number of countries in each bin.

Figure B3. Cocoa: VSS Coverage (% of VSS-certified area of total harvested area), 2021



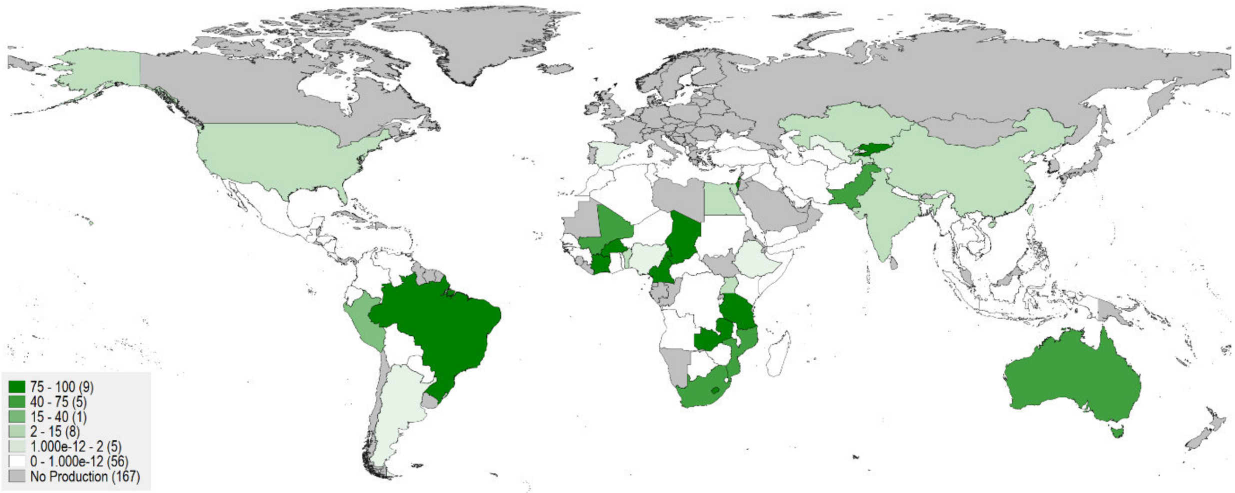
Source: Data from FiBL and the ITC. Note: This figure considers the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year). The number in parentheses represents the number of countries in each bin.

Figure B4. Coffee: VSS Coverage (% of VSS-certified area of total harvested area), 2021



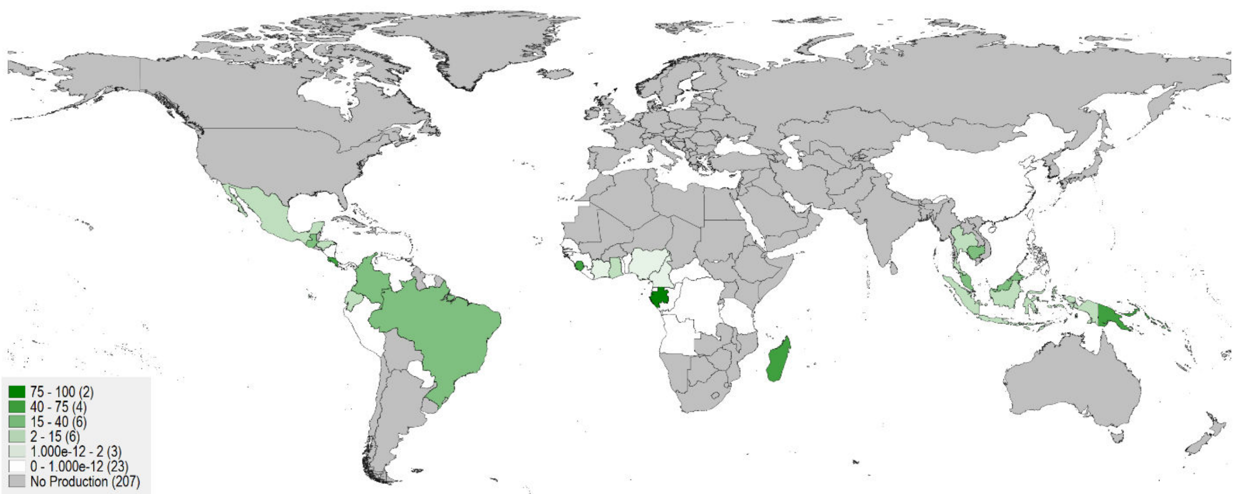
Source: Data from FiBL and the ITC. Note: This figure considers the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year). The number in parentheses represents the number of countries in each bin.

Figure B5. Cotton: VSS Coverage (% of VSS-certified area of total harvested area), 2021



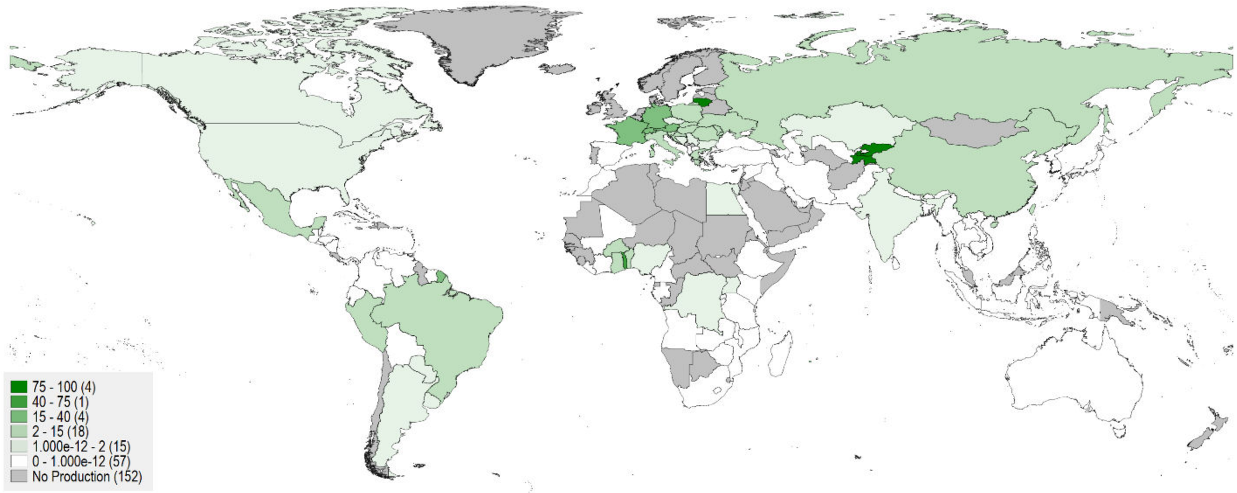
Source: Data from FiBL and the ITC. Note: This figure considers the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year). The number in parentheses represents the number of countries in each bin.

Figure B6. Palm Oil: VSS Coverage (% of VSS-certified area of total harvested area), 2021



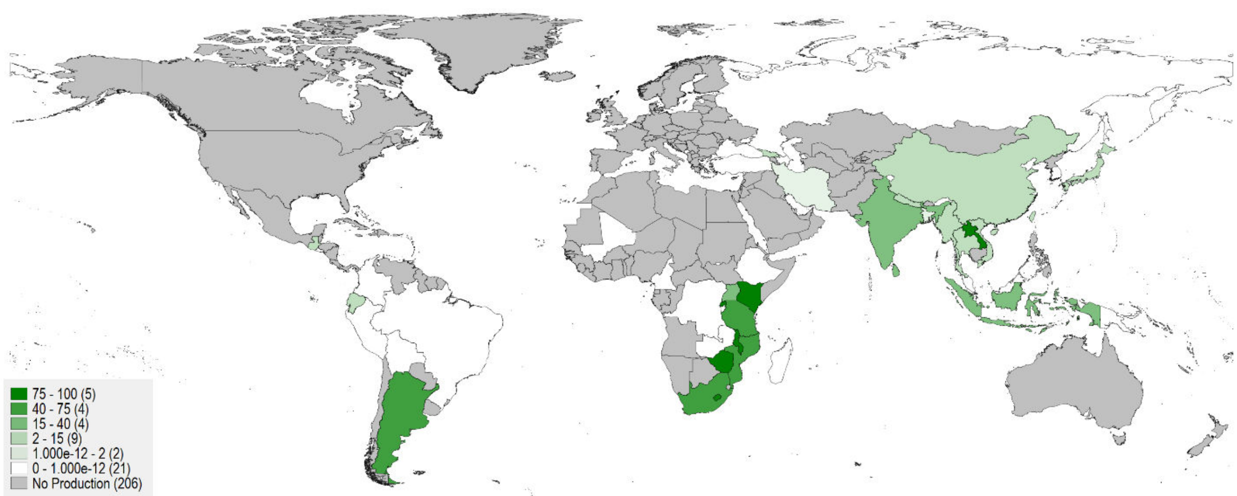
Source: Data from FiBL and the ITC. Note: This figure considers the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year). The number in parentheses represents the number of countries in each bin.

Figure B7. Soybeans: VSS Coverage (% of VSS-certified area of total harvested area), 2021



Source: Data from FiBL and the ITC. Note: This figure considers the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year). The number in parentheses represents the number of countries in each bin.

Figure B8. Tea: VSS Coverage (% of VSS-certified area of total harvested area), 2021



Source: Data from FiBL and the ITC. Note: This figure considers the minimum total certified area (i.e., the coverage of the most widespread VSS per product-country-year). The number in parentheses represents the number of countries in each bin.

C. Robustness checks

Table C1. Sensitivity to Different Fixed Effects Specifications

Model specification	FE	Controls	VSS_{ikt-1}	$\log(1 + VSS_{ikt-1})$	N
1	*it jt k ij*	1	0.0130***	0.3440***	144,679
	it jt k ij	2	0.0122***	0.3008***	97,056
2	*it jt kt ij*	1	0.0158***	0.4071***	144,679
	it jt kt ij	2	0.0149***	0.3667***	97,056
3	*it jkt ij*	1	0.0182***	0.4859***	133,631
	it jkt ij	2	0.0171***	0.4148***	91,853
4	*it jkt ijk*	1	0.0064***	-0.0090	95,518
	it jkt ijk	2	0.0075***	-0.0040	68,102
5	*it ik jkt ij*	1	-	-	132,909
	it ik jkt ij	2	-	-	91,170
6	*ik jkt ijt*	1	-	-	90,370
	ik jkt ijt	2	-	-	66,240
7	*jkt ijt*	1	0.0201***	0.5370***	90,856
	jkt ijt	2	**0.0186*** **	**0.4567*** **	66,692
8	*jkt ijt ijk*	1	0.0048**	0.0148	62,674
	jkt ijt ijk	2	0.0057**	0.0057	48,246
9	*ikt jkt ijt ijk*	1	-	-	62,624
	ikt jkt ijt ijk	2	-	-	48,198
i: exporter, *j*: importer, *k*: product, and *t*: time.					

Note: ***, **, * denote significance at 1%, 5%, and 10%, respectively. Model estimated with PPML, where the dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio in different forms. Control set (1) includes ln of production, bilateral tariffs, and a remoteness index. Control set (2) also includes the prevalence score of different NTMs. The sample is restricted to exporters that are top producers from developing countries and LAC. The fixed effects specification chosen for the baseline models is shaded gray.

Table C2: Robustness - Trade Effects of VSS adoption.

VARIABLES	(1) **OLS**	(2) **IV-OLS**	(3) **PPML**	(4) **OLS**	(5) **PPML**
$\log(1 + VSS_{ikt-1})$	0.3880***		0.4567***	0.5748***	1.0204***
	(0.0287)		(0.0467)	(0.0944)	(0.1268)
$\log(1 + VSS_{ikt-1})^2$				-0.0459**	-0.1267***
				(0.0224)	(0.0286)
$\log(1 + VSS_{ikt})$		0.7304***			
		(0.0998)			
$\log(1+tariffs_{ijkt-1})$	-2.4062**	-2.7227***	-6.7834***	-2.3237**	-6.8479***
	(0.9428)	(0.9331)	(1.0472)	(0.9396)	(1.0756)
$\log(Production_{ikt})$	1.2943***	1.2199***	1.3168***	1.2832***	1.2716***
	(0.0412)	(0.0439)	(0.0656)	(0.0414)	(0.0573)
$\ln(Remoteness_{ikt})$	0.0367	0.0201	-0.0175	-0.0059	-0.1600*
	(0.0691)	(0.0683)	(0.0930)	(0.0670)	(0.0892)
NTM^{x}_{ikt-1}	0.1071***	0.1155***	0.0011	0.1021***	-0.0128
	(0.0140)	(0.0142)	(0.0177)	(0.0144)	(0.0174)
NTM^{x}_{ijkt-1}	-1.1627***	-1.0930***	-0.3310	-1.1113***	-0.1400
	(0.3002)	(0.2933)	(0.2537)	(0.3004)	(0.2383)
NTM^{m}_{ijkt-1}	0.0221	0.0201	-0.1810	0.0182	-0.1549
	(0.1558)	(0.1562)	(0.1759)	(0.1558)	(0.1863)
Observations	115,200	114,944	66,692	115,200	66,692
SW F-Test		890,57			
SW pval		0,00			
Import-Product-Time FE	YES	YES	YES	YES	YES
Countrypair-Time FE	YES	YES	YES	YES	YES

Note: Robust country-pair-product clustered standard errors in parentheses; ***, **, * denote significance at 1, 5, and 10 percent, respectively. The dependent variable is bilateral trade transformed to ln(1+trade) in columns 1, 2, and 4. For columns 3 and 5 the dependent variable enters in levels. The independent variable is the coverage ratio of VSS, under different forms. Log of production, bilateral tariffs, a remoteness index and the prevalence score of different NTMS enter as controls. Sample restricted to consider only exporters which are top producers from developing countries. Constant was omitted for simplicity.

Table C3. Trade Effects of VSS Adoption; OLS, IV-OLS, and PPML; Different Samples and Weights

		(1)	(2)	(3)	(4)	(5)	(6)
		OLS	**IV-OLS**	**PPML**	**OLS**	**IV-OLS**	**PPML**
Independent variable from:		VSS_{ikt-1}	VSS_{ikt}	VSS_{ikt-1}	$\log(1 + VSS_{ikt-1})$	$\log(1 + VSS_{ikt})$	$\log(1 + VSS_{ikt-1})$
Top producers—developing and LAC	Estimate	**0.0188*** **	**0.0486*** **	**0.0186*** **	**0.3880*** **	**0.7304*** **	**0.4567*** **
	Standard error	(0.0018)	(0.0079)	(0.0032)	(0.0287)	(0.0998)	(0.0467)
	Observations	[115,200]	[114,944]	[66,692]	[115,200]	[114,944]	[66,692]
All producers	Estimate	**0.0132*** **	**0.0408*** **	**0.0103*** **	**0.3579*** **	**0.6375*** **	**0.3417*** **
	Standard error	(0.0008)	(0.0121)	(0.0029)	(0.0115)	(0.0541)	(0.0430)
	Observations	[468,096]	[443,904]	[212,018]	[468,096]	[443,904]	[212,018]
Top producers	Estimate	**0.0186*** **	**0.0476*** **	**0.0113*** **	**0.3799*** **	**0.7554*** **	**0.4037*** **
	Standard error	(0.0018)	(0.0075)	(0.0038)	(0.0284)	(0.1008)	(0.0653)
	Observations	[120,960]	[118,400]	[70,514]	[120,960]	[118,400]	[70,514]
Developing countries	Estimate	**0.0142*** **	**0.0337*** **	**0.0152*** **	**0.3646*** **	**0.6746*** **	**0.3414*** **
	Standard error	(0.0008)	(0.0120)	(0.0027)	(0.0121)	(0.0603)	(0.0348)
	Observations	[410,752]	[392,832]	[188,735]	[410,752]	[392,832]	[188,735]
Weighted all producers—area	Estimate	**0.0216*** **	**0.2234*** **	**-0.0005**	**0.5370*** **	**1.7511*** **	**0.2338***
	Standard error	(0.0029)	(0.0305)	(0.0043)	(0.0410)	(0.2515)	(0.1237)
	Observations	[468,096]	[443,904]	[212,018]	[468,096]	[443,904]	[212,018]
Weighted all producers—production	Estimate	**0.0239*** **	**0.9738*** **	**-**	**0.5124*** **	**1.1737*** **	**-**
	Standard error	(0.0030)	(0.2410)	-	(0.0435)	(0.1917)	-
	Observations	[468,096]	[443,904]	-	[468,096]	[443,904]	-
Weighted developing countries—area	Estimate	**0.0229*** **	**0.5382*** **	**0.0032**	**0.5829*** **	**1.9397*** **	**0.2793** **
	Standard error	(0.0029)	(0.1316)	(0.0052)	(0.0414)	(0.2210)	(0.1147)
	Observations	[410,752]	[392,832]	[188,735]	[410,752]	[392,832]	[188,735]
Weighted developing countries—production	Estimate	**0.0278*** **	**-7.7493**	**-**	**0.6023*** **	**1.7548*** **	**-**
	Standard error	(0.0031)	(14.4462)	-	(0.0463)	(0.2355)	-
	Observations	[410,752]	[392,832]	-	[410,752]	[392,832]	-

Note: Robust country-pair-product standard errors are clustered in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. Number of observations in brackets. The dependent variable is bilateral trade transformed to ln(1+trade) in columns 1, 2, 4, and 5. In columns 3 and 6, the dependent variable is entered in levels. The independent variable is the VSS coverage ratio, in different forms. Log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMS are included as controls.

Table C4. Trade Effects of VSS Adoption; Alternative Definitions of VSS Coverage

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	PPML	PPML	PPML	PPML	PPML	PPML	PPML	PPML
Independent variable	VSS^{MAX}_{ikt-1}		VSS^{AVG}_{ikt-1}		$\log(1 + VSS^{MAX}_{ikt-1})$		$\log(1 + VSS^{AVG}_{ikt-1})$	
	0.0139***	0.0123***	0.0348***	0.0330***	0.5631***	0.4877***	0.5780***	0.4927***
	(0.0022)	(0.0022)	(0.0040)	(0.0042)	(0.0426)	(0.0442)	(0.0502)	(0.0538)
Observations	90,856	66,692	90,856	66,692	90,856	66,692	90,856	66,692
Imp.-prod.-time FE	YES	YES	YES	YES	YES	YES	YES	YES
Exp.-imp.-time FE	YES	YES	YES	YES	YES	YES	YES	YES
Controls	1	2	1	2	1	2	1	2

Note: Robust country-pair-product standard errors are clustered in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio, in different forms. The log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMs are included as controls. Control set (1) includes ln of production, bilateral tariffs, and a remoteness index. Control set (2) also includes the prevalence score of different NTMs. The sample is restricted to exporters that are top producers from developing countries and LAC.

Table C5. Trade Effects of VSS Adoption; OLS, IV-OLS, and PPML; Robustness of VSS Coverage

Variables	(1) OLS	(2) IV-OLS	(3) PPML	(4) OLS	(5) IV-OLS	(6) PPML
d.VSS_{ikt}	-0.0157***		0.0276**			
	(0.0031)		(0.0131)			
d.VSS_{ikt}		0.0675***				
		(0.0200)				
VSS_{ikt-1}				0.0095***		0.0138***
				(0.0021)		(0.0029)
VSS_{ikt}					0.0836***	
					(0.0146)	
Observations	12,800	12,800	5,209	115,200	114,944	66,692
Fixed effects	jk ij	jk ij	jk ij	jkt ijt	jkt ijt	jkt ijt
Sample	Top producer and developing countries (all LAC)	Top producer and developing countries (all LAC)	Top producer and developing countries (all LAC)	Top producer and developing countries (all LAC)	Top producer and developing countries (all LAC)	Top producer and developing countries (all LAC)
SW F-test		20.19			287.56	
SW pval		7.0570E-06			0.00	

Note: Robust country-pair-product standard errors are clustered in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is bilateral trade transformed to ln(1+trade) in columns 1, 2, 4, and 5. For columns 3 and 6, the dependent variable is entered in levels. The independent variable is the VSS coverage ratio, in different forms. For columns 1–3, it is the difference in the average VSS coverage for the last three years of our sample (2019–2021) and the first three years of our sample (2013–2015). For columns 4–6, it is the VSS coverage ratio. The log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMs are included as controls. The set of controls includes the ln of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMs. The sample is restricted to exporters that are top producers from developing countries and LAC.

Table C6. Robustness—Trade Effects of VSS Adoption By Commodity

	World	**World**	**World**	**World**	**World**	**World**	**World**
Variables	PPML	PPML	PPML	PPML	OLS	PPML	OLS
(VSS_{ikt-1}) x banana	0.0420***	0.0492***	0.0252***	0.0903***	0.0565***	0.0465***	0.0350***
	(0.0080)	(0.0086)	(0.0047)	(0.0152)	(0.0058)	(0.0052)	(0.0033)
(VSS_{ikt-1}) x sugarcane	0.0027	0.0337	-0.0042	0.0139	0.0253*	0.0387***	0.0176***
	(0.0230)	(0.0206)	(0.0209)	(0.0496)	(0.0135)	(0.0100)	(0.0023)
(VSS_{ikt-1}) x cocoa	-0.0138*	0.0083	-0.0105**	-0.0442**	0.0135*	-0.0001	0.0107***
	(0.0081)	(0.0054)	(0.0041)	(0.0178)	(0.0074)	(0.0060)	(0.0022)
(VSS_{ikt-1}) x coffee	-0.0016	0.0010	-0.0070*	-0.0114	0.0550***	0.0123	0.0513***
	(0.0072)	(0.0063)	(0.0037)	(0.0146)	(0.0057)	(0.0091)	(0.0023)
(VSS_{ikt-1}) x cotton	0.0098**	0.0099**	0.0121**	-0.0112	0.0168***	-0.0004	0.0001
	(0.0049)	(0.0047)	(0.0050)	(0.0099)	(0.0030)	(0.0036)	(0.0014)
(VSS_{ikt-1}) x palm oil	0.0400***	0.0393***	0.0387***	0.0579***	0.0108**	0.0183***	0.0065**
	(0.0056)	(0.0055)	(0.0056)	(0.0117)	(0.0046)	(0.0046)	(0.0026)
(VSS_{ikt-1}) x soybeans	0.2810*	0.2869**	0.2315**	-0.3339*	0.1757	0.0573***	0.0118***
	(0.1474)	(0.1433)	(0.1077)	(0.2021)	(0.1151)	(0.0138)	(0.0030)
(VSS_{ikt-1}) x tea	0.0365***	0.0228***	0.0386***	0.0121	-0.0016	0.0029	0.0057***
	(0.0081)	(0.0058)	(0.0079)	(0.0206)	(0.0035)	(0.0037)	(0.0015)
Observations	66,692	90,856	66,692	66,692	115,200	212,018	468,096
Import-product-time FE	YES	YES	YES	YES	YES	YES	YES
Exporter-importer-time FE	YES	YES	YES	YES	YES	YES	YES
Sample	Top producer and developing country (all LAC)	Top producer and developing country (all LAC)	Top producer and developing country (all LAC)	Top producer and developing country (all LAC)	Top producer and developing country (all LAC)	All producers	All producers
Controls	2	1	2	2	2	2	2
Weighted				Area			
Independent Variable	Min coverage	Min coverage	**Max coverage**	Min coverage	Min coverage	Min coverage	Min coverage

Note: Robust country-pair-product standard errors are clustered in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is bilateral trade transformed to ln(1+trade) in columns 1, 2, 4, and 5. For columns 3 and 6, the dependent variable is entered in levels. The independent variable is the VSS coverage ratio, in different forms . The log of production, and bilateral tariffs are included as controls. The sample is restricted to exporters that are major producers of each commodity.

Table C7. Robustness—Trade Effects of VSS Adoption by Commodity and Exporting Region

Variables	Latin America and Caribbean PPML	East and South Asia and Pacific PPML	Sub-Saharan Africa PPML	Latin America and Caribbean PPML	East and South Asia and Pacific PPML	Sub-Saharan Africa PPML
(VSS_{ikt-1}) x banana	0.0210***	1.7804	2.0953***	0.0361***	0.1286***	-0.0338**
	(0.0060)	(1.1366)	(0.3148)	(0.0053)	(0.0182)	(0.0165)
(VSS_{ikt-1}) x sugarcane	-0.0741**	0.0489**		0.0141	0.0441***	0.0182***
	(0.0367)	(0.0235)		(0.0103)	(0.0159)	(0.0047)
(VSS_{ikt-1}) x cocoa	0.0030	0.1339**	-0.0284**	0.0107	-0.6471***	-0.0157
	(0.0103)	(0.0659)	(0.0117)	(0.0070)	(0.2438)	(0.0121)
(VSS_{ikt-1}) x coffee	0.0059	0.0214	0.0020	0.0086	0.0396***	0.0445***
	(0.0078)	(0.0151)	(0.0084)	(0.0060)	(0.0106)	(0.0061)
(VSS_{ikt-1}) x cotton	-0.0021	-0.0151	-0.0097***	0.0043	0.0134	0.0061*
	(0.0055)	(0.0422)	(0.0036)	(0.0048)	(0.0429)	(0.0034)
(VSS_{ikt-1}) x palm oil	0.0274***	0.0417***	0.2123***	0.0086	0.0332***	0.1541***
	(0.0077)	(0.0086)	(0.0565)	(0.0053)	(0.0082)	(0.0547)
(VSS_{ikt-1}) x soybeans	0.0037	0.4401		-0.0597	0.4431	0.0589***
	(0.0975)	(0.5504)		(0.0465)	(0.3524)	(0.0126)
(VSS_{ikt-1}) x tea	-0.0471*	0.0503**	0.1222***	-0.0248***	0.0271*	0.0106***
	(0.0259)	(0.0205)	(0.0249)	(0.0089)	(0.0139)	(0.0036)
Observations		66,692			188,735	
Import-product-time FE		YES			YES	
Exporter-importer-time FE		YES			YES	
Sample	Top producers and developing countries			Developing countries		
Controls		2			2	

Note: Robust country-pair-product standard errors are clustered in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio, which was interacted with exporting region and product dummies. The log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMs are included as controls but are not displayed here. Columns 1–3 present the results for a sample that considers only exporters that are top producers from developing countries and LAC. Columns 4–5 present the results for a sample including all developing countries. The "other regions" group was omitted for simplicity. It includes developing countries from regions where not many countries produce the commodities included in this study, such as Europe and Central Asia and the Middle East and North Africa.

Table C8: Trade Effects of VSS Adoption by Exporter and Importer Income Level

	Importer			
	High-income	**Upper-middle-income**	**Lower-middle-income**	**Low-income**
	PPML	PPML	PPML	PPML
VSS_{ikt-1} x upper-middle-income	0.0219***	0.0077	-0.0150***	-0.0226
	(0.0041)	(0.0068)	(0.0057)	(0.0252)
VSS_{ikt-1} x lower-middle-income	0.0470***	0.0255***	0.0747***	-0.0030
	(0.0061)	(0.0057)	(0.0129)	(0.0127)
VSS_{ikt-1} x low-income	0.2041***	0.1546***	0.1270***	-0.0112
	(0.0172)	(0.0400)	(0.0195)	(0.0153)
Observations		66,692		
Import-product-time FE		YES		
Exporter-importer-time FE		YES		
Sample		Top producers and developing countries		

Note: Robust country-pair-product standard errors are clustered in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio, which was interacted with exporting and importing country income group dummies. The log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMs are included as controls but are not displayed here. The sample is restricted to exporters that are top producers from developing countries and LAC.

Table C9. Trade Effects of VSS Adoption by Exporting Region and Importer Income Group

	High-income	**Upper-middle-income**	**Lower-middle-income**	**Low-income**	Obs.	*jkt*—FE	*ijt*—FE
	PPML	PPML	PPML	PPML			
VSS$_{ikt-1}$ x world	0.0277***	0.0114*	-0.0079	-0.0079	66,692	YES	YES
	(0.0034)	(0.0064)	(0.0052)	(0.0128)			
VSS$_{ikt-1}$ x Latin America and Caribbean	**0.0196*** **	**0.0077**	**-0.0172*** **	**-0.1427** **			
	(0.0045)	(0.0070)	(0.0048)	(0.0707)			
VSS$_{ikt-1}$ x East and South Asia and Pacific	0.0576***	0.0283***	0.0252	-0.0295			
	(0.0061)	(0.0079)	(0.0186)	(0.0403)	66,692	YES	YES
VSS$_{ikt-1}$ x Sub-Saharan Africa	0.0337***	0.0264***	0.0798***	0.0653***			
	(0.0083)	(0.0072)	(0.0179)	(0.0173)			
VSS$_{ikt-1}$ x other regions	-0.2451***	-0.5436***	-0.3233***	0.0315			
	(0.0208)	(0.0631)	(0.0628)	(0.0539)			
Panel B—Sample: All developing countries							
	High-income	**Upper-middle-income**	**Lower-middle-income**	**Low-income**	Obs.	*jkt*—FE	*ijt*—FE
	PPML	PPML	PPML	PPML			
VSS$_{ikt-1}$ x World	0.0253***	0.0041	-0.0059	-0.0027	188,735	YES	YES
	(0.0027)	(0.0054)	(0.0040)	(0.0078)			
VSS$_{ikt-1}$ x Latin America and Caribbean	**0.0257*** **	**-0.0001**	**-0.0198*** **	**-0.0804** **			
	(0.0037)	(0.0059)	(0.0040)	(0.0378)			
VSS$_{ikt-1}$ x East and South Asia and Pacific	0.0422***	0.0187**	0.0062	-0.0082			
	(0.0056)	(0.0095)	(0.0121)	(0.0288)	188,735	YES	YES
VSS$_{ikt-1}$ x Sub-Saharan Africa	0.0144***	0.0170***	0.0253***	0.0042			
	(0.0039)	(0.0046)	(0.0060)	(0.0089)			
VSS$_{ikt-1}$ x other regions	-0.1025***	-0.0562***	-0.0860**	0.0165			
	(0.0374)	(0.0217)	(0.0378)	(0.0493)			

Note: Robust country-pair-product standard errors are clustered in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively. The dependent variable is bilateral trade in levels. The independent variable is the VSS coverage ratio, which was interacted with exporting region dummies and importing country income group dummies. The log of production, bilateral tariffs, a remoteness index, and the prevalence score of different NTMs are included as controls but are not displayed here. The sample contains exporters that are top producers from developing countries and LAC in panel A and from all developing countries in panel B. The "other regions" group contains developing countries from regions where not many countries produce the commodities included in this study, such as Europe and Central Asia and the Middle East and North Africa.

Table C10: Trade Effects of VSS adoption conditional on global and partner's VSS coverage

VARIABLES	(1) PPML	(2) PPML	(3) PPML	(4) PPML	(5) PPML	(6) PPML	(7) PPML	(8) PPML
VSS_{ikt-1}	0.0408***	0.0474***	0.0421***	0.0433***	0.0367***	0.0427***	0.0383***	0.0394***
	(0.0061)	(0.0058)	(0.0038)	(0.0035)	(0.0058)	(0.0056)	(0.0037)	(0.0034)
VSS $Global_{ikt-1}$ x VSS_{ikt-1}	-0.0019***	-0.0020***	-0.0019***	-0.0019***				
	(0.0004)	(0.0003)	(0.0002)	(0.0002)				
VSS $Others_{ikt-1}$ x VSS_{ikt-1}					-0.0015***	-0.0018***	-0.0016***	-0.0017***
					(0.0004)	(0.0004)	(0.0003)	(0.0002)
VSS $Others_{ikt-1}$					0.0532**	0.0284	0.0423*	0.0226
					(0.0253)	(0.0239)	(0.0226)	(0.0211)
ln(Production $Others_{ikt}$)	0.3063	-0.9658*	-3.3479***	-3.4887***	0.3363	-1.0091**	-3.3470***	-3.5021***
	(0.5666)	(0.4958)	(0.5033)	(0.4508)	(0.5752)	(0.4980)	(0.5061)	(0.4549)
ln(1+$tariffs_{ijkt-1}$)	-6.4414***	-5.8632***	-3.3707***	-3.3894***	-6.1883***	-5.6962***	-3.2945***	-3.3277***
	(1.0383)	(1.0163)	(0.5516)	(0.5360)	(1.0339)	(0.9983)	(0.5427)	(0.5307)
ln($Production_{ikt}$)	1.4925***	1.2585***	0.8692***	0.8568***	1.4932***	1.2461***	0.8664***	0.8531***
	(0.1151)	(0.0986)	(0.0562)	(0.0484)	(0.1167)	(0.0994)	(0.0564)	(0.0484)
ln($Remoteness_{ikt}$)	0.0345	-0.0250	-0.0123	-0.0434	0.0629	0.0033	0.0141	-0.0221
	(0.0963)	(0.0866)	(0.0891)	(0.0787)	(0.0975)	(0.0870)	(0.0901)	(0.0789)
NTM^{x}_{ikt-1}	0.0144		0.0325*		0.0195		0.0356**	
	(0.0185)		(0.0172)		(0.0195)		(0.0176)	
NTM^{x}_{ijkt-1}	-0.6367**		-0.2168		-0.6782**		-0.2351	
	(0.2641)		(0.2342)		(0.2682)		(0.2368)	
NTM^{m}_{ijkt-1}	-0.1903		-0.2185*		-0.2079		-0.2349*	
	(0.1884)		(0.1234)		(0.1866)		(0.1265)	
Constant	-11.8101	17.2008*	66.985***	70.874***	-13.8362	17.0087*	65.734***	70.271***
	(11.7803)	(10.2484)	(9.8250)	(8.9003)	(12.0471)	(10.3305)	(9.9237)	(9.0421)
Observations	66,692	90,856	188,735	279,343	66,692	90,856	188,735	279,343
Import-Product-Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Exporter-Importer-time FE	YES	YES	YES	YES	YES	YES	YES	YES
Sample	Top Producers	Top Producers	Developing	Developing	Top Producers	Top Producers	Developing	Developing

Note: Robust country-pair-product clustered in parentheses; ***, **, * denote significance at 1, 5, and 10 percent, respectively. The dependent variable is bilateral trade in levels. The independent variable is the coverage ratio of VSS. This variable is interacted with the global coverage of VSS for columns 1-4 and with the VSS coverage of all other countries except the exporting country in columns 5-8. We further include multiple controls variables. We alternate between sets 1 and 2 of controls, all displayed in the table. Sample includes all developing countries and LAC.