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Product quality and sustainability: The effect of international environmental agreements on bilateral trade

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1 | INTRODUCTION

In previous years, more and more countries have been signing agreements, which aim at increasing the level of sustainable natural resource management practices. They do this by unilaterally imposing stricter regulations for trade in natural resources to ban unsustainably managed products from their markets. The International Tropical Timber Agreement (ITTA) can be seen as an important example of such an effort. Tropical timber producers acceding to the ITTA commit themselves to provide a higher sustainability standard in the tropical timber production. Tropical timber consumers as ITTA members reveal a higher preference for goods that comply with this standard. The increase in sustainability induced by the ITTA can be interpreted as an improvement of overall product quality,[1] which should manifest itself in the value of international trade flows of tropical timber.

We address the following research questions in this paper. First, we ask whether the sustainability standard induced by the ITTA influences the firms' decision in the exporting country to serve a foreign market with tropical timber and whether the ITTA indeed leads to a quality improvement of the observed trade flows in addition to a reduction in trade barriers. This question is motivated by the large literature on the impact of product standards on international trade (Chen & Matoo, 2008; Czubala, Shepherd, & Wilson, 2009; Disdier, Fontagne, & Cadot, 2015). Second, recent studies show that product standards affect international trade differently depending on specific product characteristics (Fajgelbaum, Grossman, & Helpman, 2011; Hallak, 2010; Shepherd & Wilson, 2013). In addition, motivated by the contributions of Murray, McCarl, and Lee (2004), Wear and Murray (2004) and Chen and Matoo (2008), we ask how the ITTA, where only a fraction of the market participants increase their supply of and/or demand for sustainably produced tropical

[1]Throughout this paper, we define the overall product quality of tropical timber as a combination of a baseline quality component and a second component that refers to sustainably managed tropical timber as defined by the agreement.

timber, affects the distribution of the tropical timber trade for participating and for non-participating countries.

To answer these research questions, we extend the trade model of Hallak (2010) to identify the impact of overall product quality on bilateral trade flows. We explicitly distinguish between (i) a baseline quality component as introduced by Hallak (2010) and (ii) a sustainable product quality component that refers to sustainability in the tropical timber production, which is induced by the ITTA implementation itself. The sustainable product quality component involves both, supplying higher quality by guaranteeing sustainable production and the higher valuation of sustainable production by the consumers. The advantage of this approach is that we are able to decompose the ITTA-induced trade effect into a supplied sustainable *product standard effect* and a consumers' *environmental preference effect* for sustainable tropical timber. This gives us a detailed view on how the introduction of a sustainable product standard agreement determines trade patterns.

The econometric specification is based on a gravity model of international trade, which explicitly accounts for differences in the sustainability of production and preferences for sustainable production. The econometric approach addresses the potential systematic selection of countries to start international trade considering the role of product standards as accounted for in, for example Chen, Wilson, and Otsuki (2008) and Czubala et al. (2009). By using the structural gravity model of Anderson and van Wincoop (2003) in a difference-in-difference design, we are able to determine the causal direct effect as well as third-country effects induced by the ITTA.

This paper extends the relevant literature in two ways. First, we combine the literature on the sectoral influence of production standards (Shepherd & Wilson, 2013) and the literature on the impact of product quality on sectoral trade (Fajgelbaum et al., 2011; Hallak, 2010). Second, we conduct a comprehensive comparative static analysis. Based on the estimated parameters of the gravity model, we solve the structural gravity model with and without the ITTA. We thereby explicitly allow for changes in the multilateral resistance terms. This enables us to estimate the trade impact of an increase in sustainable product quality induced by the ITTA for participating as well as for third countries. To the best of our knowledge, this is the first empirical study, which examines the third-country trade effect of a unilaterally implemented sustainability standard.

Our results show that product quality matters and that it plays a central role in forming international trade patterns of tropical timber. Concerning the indicators for the sustainable product quality component, we find for both, the consumers' environmental preference and the producers' capability to supply sustainable product quality, a theory consistent positive and significant influence on the probability as well as the value of tropical timber trade flows. The counterfactual analysis shows that exporters as well as importers can considerably increase their value of tropical timber trade flows by either increasing their sustainable tropical timber production or by committing themselves to demand more sustainably produced tropical timber. Because of a change in multilateral resistances, third countries are also affected by an introduction of the ITTA. The results for these countries reveal a negative trade effect. Finally, the trade impact of the ITTA is not homogenous for every country in our sample. In particular, small countries, which accede to the ITTA, can benefit from a change to sustainably produced tropical timber.

The remainder of the paper is organised as follows. In Section 2, we introduce the agreement of our interest, the International Tropical Timber Agreement, and give a brief overview of the relevant literature. In Section 3, we describe our theoretical and empirical approach to analyse the trade effects of the ITTA. In Section 4, we present our data, and in Section 5, we discuss the estimation results and counterfactual analyses. The last section concludes.

2 | BACKGROUND AND PREVIOUS LITERATURE

In 2016, global trade in forest products amounts to US$227 billion. Tropical timber trade sums up to 36% of global exports of roundwood and 15.6% of global exports of sawnwood. In case of imports, tropical timber amounts to 31.2% of global roundwood imports and 15.7 of global sawnwood imports (ITTA 2016).

In our study, we focus on hardwoods and distinguish between two broad classes of timber, namely tropical and non-tropical timber. According to the ITTA, tropical timber is defined as non-coniferous tropical timber for industrial uses, which is produced in the countries situated between the Tropic of Cancer and the Tropic of Capricorn (ITTA 1994). Typical tropical timber species, as considered by the ITTA, are, for example, mahogany, meranti, rosewood or virola.[2] Non-tropical hardwood timber species, which also occur in tropical forests, are, for example, oak, beech, cherry and ash (Nixon, 2006; Peters, 1997; Primack, Higuchi, & Miller-Rushing, 2009; Singh, Malik, & Sharma, 2016). Tropical and non-tropical hardwood is typically used for furniture making, boat building and flooring. Although, there are some uses in which tropical timber is hardly substitutable, for example, in the production of some musical instruments, there is, in general, substitution between these different types (Brockmann, Hemmelskamp, & Hohmeyer, 1996; Gan, 2005; Vincent, Brooks, & Gandapur, 1991). In recent years, for example, tropical timber got increasingly replaced by domestic hardwoods in European markets (Jonsson, Mbongo, Felton, & Boman, 2012).

From 2000 until 2015, the annual value of global trade in forest products has increased by 57%. As global demand of forest products increases, the pressure on the forest stock increases as well. The FAO (2016) estimates that between 2000 and 2010, the loss in forest area in the tropics was around 7 million hectares per year. To improve the governance and sustainability of the timber production and trade, various policy measures are implemented. Examples of such measures are a recent amendment of the US Lacey Act, 2008 (Section 8204), the Australian Illegal Logging Prohibition Bill, 2012, the EU Timber Regulation No 995/2010, which entered into force in March 2013, and the measure of interest in this study, the International Tropical Timber Agreement. They intend to reduce the amount of illegally harvested and/or unsustainably managed timber by increasing the demand for sustainable tropical timber in the importing countries and regulating the production standards in the exporting countries.

We selected the ITTA for our analysis based on two reasons. First, the ITTA has been in force for a longer period of time than the US Lacey Act 2008, the Australian Illegal Logging Prohibition Bill 2012 and the EU Timber Regulation 2013. And second, only a small number of importing countries are taking part in the US Lacey Act 2008 (United States), the Australian Illegal Logging Prohibition Bill 2012 (Australia) and the EU Timber Regulation 2013 (the 28 EU countries), which makes it difficult to take the importer countries' heterogeneity in their preferences for sustainably produced timber into account.

2.1 | The international tropical timber agreement

In 1986, following a growing public debate on the substantial degradation and destruction of the world's forests, an international environmental agreement on the management of and trade in tropical timber—the so-called International Tropical Timber Agreement—entered into force. Under the agreement, the International Tropical Timber Organization, with its decision-making and

[2]For a complete list of species, covered by the ITTA, see ITTA (2016).

recommendatory body, the International Tropical Timber Council, was established. The ITTA's objective is the protection of natural tropical forests from destruction, degradation and excision. In addition, the agreement aims at promoting trade in high quality, sustainably managed tropical timber. Until now, the original agreement was renegotiated twice, in 1994 as well as in 2006.[3]

Originally, the ITTA was designed as a commodity-based agreement to strengthen the members' tropical timber markets.[4] This focus shifted with the 1994 ITTA which includes the "ITTO Objective 2000" and the Bali Partnership Fund. These two measures have substantially increased the importance of the sustainable use of the forest resource. For instance, forest certification schemes, developing criteria and indicators for sustainable management were implemented. Community forestry schemes were introduced, and harvesting data of tropical timber were made more transparent. The Bali Partnership Fund as part of the 1994 ITTA allocates financial assistance for the implementation of sustainable tropical timber management.

As part of the agreement's objectives, member countries have emphasised the desirability of producing and consuming sustainably managed tropical timber and acknowledged the accompanying price increase, namely by:

> promoting improved understanding of the structural conditions … which reflect the costs of sustainable forest management; (Objective (e), ITTA 1994)

> promoting increased and further processing of tropical timber from sustainable sources in producer member countries, with a view to promoting their industrialisation and thereby increasing their employment opportunities and export earnings.
> (Objective (i), ITTA 1994)

The member countries' performance in fulfilling the agreement's objectives is reviewed annually based on information submitted by the countries themselves, experts and international organisations. Following Article 44 of the 1994 ITTA by decision of the International Tropical Timber Council, countries defecting significantly from these objectives can be excluded from the agreement. However, due to the voluntary characteristics of the agreement and to the best of our knowledge, no country has been officially excluded by the council. The 1994 ITTA was signed by 65 member countries whereof the producing member countries possess about 80% of the world's tropical forests.

2.2 | The impact of standards on international timber trade

The adoption of sustainable forestry management standards, as proposed by the ITTA and other timber trade-related policy measures, such as certification programmes (e.g., the Forest Stewardship Council or the Programme for the Endorsement of Forest Certification Schemes) or direct trade regulation (e.g., the amendment of the US Lacey Act, 2008, Section 8204, the Australian Illegal

[3]Our indicator variable for the ITTA membership refers to the 1994 ITTA. However, if countries already signed the 1983 ITTA as well as the 1994 ITTA, the dummy captures not only the effect of the 1994 ITTA but the overall effect of the ITTA membership. The 2006 revision was not taken into account because it did not into force until 2011.

[4]To ensure conformability with the WTO rules, Article 36 of the 1994 ITTA explicitly states that member countries are not allowed to use measures to restrict or ban international trade in timber and timber products. We therefore assume that non-tropical importers do not misuse ITTA as a non-tariff measure to protect their domestic producers by increasing the costs of timber producers in tropical countries.

Logging Prohibition Bill 2012 or the EU Timber Regulation No 995/2010), can have various economic effects on international timber trade. On the one hand, these standards aim to harmonise and assist regulation procedures, to increase the transparency in the supply chain, (e.g., by developing criteria and indicators for the sustainable management of forests) and to provide better product information. This reduces business transaction costs and enables a better matching of preferences for quality and the supplied level of quality. Further, the standard setting organisations often provide forest management education and information programmes to increase the quality and reliability of production (Blackman & Rivera, 2011). On the other hand, sustainability standards can also restrict the competitiveness of industries by reducing the available resource stock and raising compliance costs, which also includes costs due to a change in forest management, employee training and auditing complexities (Rodrigue & Soumonni, 2014).

Empirically, the size and distribution of the economic impact of the implementation of sustainable forestry management standards in producing and consuming countries depends on characteristics of the affected industry and the specificity and strictness of the standard. In an early study, Sohngen, Mendelsohn, and Sedjo (1999) determine the impact of a conservation policy, which protects 5% and 10% of forestland in North America and Europe, respectively, on global timber markets using a computable general equilibrium modelling approach. They conclude that the average area of land, harvested in regions with no protection policy, increases by 1.4%. Furthermore, due to a higher world price, the harvest in former inaccessible forest areas would increase by approximately 1 ha for every 20 ha conserved forest in North America and Europe. Wear and Murray (2004) study the impact of the 1973 Endangered Species Act to protect the habitat of the northern spotted owl in the major forests in the US Pacific Northwest region on US and Canadian timber markets and production. Their results indicate an price increase by about 15%. Further, reductions in quantity due to the conservation policy were offset by quantity increases in production by non-regulated southern US regions and Canada. Gan (2005) determines an 5%–25% increase in certification cost when analysing the impact of forest certification on output price, which leads to a decline in forestry output up to 5% and an increase in world market prices by 1.6%–34.6%. Gan and McCarl (2007) determine the magnitude and distribution of a shift in production and trade patterns due to a forest conservation policy on a global scale using computable general equilibrium modelling. Due to transnational substitution of forest products, they show that a 1% reduction in forestry output in a single country would have only a moderate impact on the world price of forestry products by about 0.5%. However, if all countries in the world simultaneously reduce forestry output by 1%, the world price of forestry products increases by 8.5%. Li, Buongiorno, Turner, Zhu, and Prestemon (2008) analyse the impact of long-term effects of policies, which gradually reduces the amount of illegally logged timber in the world markets, on prices and welfare. They find a small price increase of on average 1.5%–3.5%, however, with a large variation depending on the degree of prevalent illegal logging in a country. Bosello, Parrado, and Rosa (2013) use a computable general equilibrium model to determine the impact of the EU Timber Regulation No 995/2010 on production and trade. Their simulation show a decrease in international timber trade, which is replaced by an increase in intra-European Union production. Examining the impact of the amendment of the US Lacey Act 2008 and the European Union Voluntary Partnership Programme, Gan, Cashore, and Stone (2013) find both an increase in prices and increase in quantity of timber stemming from unregulated sources. In a recent time series study on the trade impacts of the amendment of the US Lacey Act 2008, Prestemon (2015) finds a double-digit percentage increase in prices of regulated tropical timber imports in the United States. With regard to the ITTA, Houghton and Naughton (2017) find that membership in the ITTA does not decrease exports of timber in general, but leads to shift across timber categories.

To conclude, previous literature point at: (i) an increase in the price of regulated timber because of an increase in marginal costs of production; (ii) a decrease in quantity, which points at a price elastic demand; and (iii) a substitution between domestic and international timber products and between regulated and unregulated areas.

3 | THEORETICAL MODEL AND EMPIRICAL SPECIFICATION

3.1 | Theoretical framework

In general, the quality of timber depends on climate and soil characteristics at point of origin. Further, production standards and consumption preferences differ between countries. Timber differs by species and species baskets differ by producer country (Prestemon, 2015; Sauquet et al., 2011). We therefore, base our empirical analysis of the impact of the ITTA on tropical timber trade on a gravity model with monopolistic competition among $i = 1, \ldots, I$ timber-exporting countries in $j = 1, \ldots, J$ timber-importing countries (markets) as laid out in Anderson and van Wincoop (2003), Anderson and Yotov (2010) and Hallak (2010). Accordingly, we assume that the demand of country j for country i's tropical and nontropical timber exports X_{ijk} is based on CES preferences with substitution elasticity $\sigma > 1$.[5] Trade flows with index $k = 0$ refer to nontropical timber, while $k = 1$ stands for tropical timber. These two types of timber are treated as variants of the same good, and we assume that timber is additionally differentiated by firms (and thus by the country of origin).

Tropical and nontropical timber-producing firms use inputs w_{ik} of the forest stock W_i in country i. Depending on the quality they provide, firms exhibit different input coefficients to produce timber products that can be sold to the market. Similar to the approach of Krugman (1980), the technology of a typical firm producing timber in our model is given as:

$$w_{ik} = a + \theta_{ik}^{b} y_{ik},$$

where y_{ik} denotes the output of a typical firm. Based on Hallak (2010), θ_{ik} is a quality indicator of production that affects factor demand with elasticity $b > 1$, differs across timber types and increases in the level of quality of production, for example, if firms commit themselves to sustainable production of timber. Lastly, a represents the fixed inputs of a timber-producing firm.

The price of a unit of the forest stock is denoted by c_i, and monopolistic competition implies that firms set factory gate prices with a markup of $\sigma/(\sigma - 1)$:

$$p_{ik} = \frac{\sigma}{\sigma - 1} \theta_{ik}^{b} c_{i},$$

where $\theta_{ik}^{b} c_i$ denotes the marginal costs of timber production that increase in the supplied quality with elasticity b.[6] Markup pricing implies that higher quality is always reflected in higher prices. Following Krugman (1980), in each country i, there are n_i timber harvesting firms. Free entry

[5]Previous literature supports the assumption of a price elastic demand (Brooks, 1994; Cengel & McKillop, 1990; Chen, Ames, & Hammett, 1988; Chou & Buongiorno, 1983; Prestemon, 2015).

[6]Ideally, one would like to use a dynamic setting, where the forest stocks are allowed to be depleted over time. In such a setting, the ITTA is expected to establish a sustainable timber harvesting rate. So, the ITTA may affect the available stock of tropical timber and thus the marginal costs of timber production in the long run. However, on the one hand, our cross-sectional data rule out estimating a dynamic gravity model. On the other hand, a dynamic structural gravity model of trade in natural resources seems to be unavailable in the literature and is beyond the scope of the present paper.

implies zero profits and determines the output of a firm as $y_{ik} = a\theta_{ik}^{-b}(\sigma - 1)$, while the endowments with timber, W_i, pin down the number of firms:

$$W_i = n_i(a + \theta_{ik}^{b} y_{ik}) = n_i a\sigma \rightarrow n_i = \frac{W_i}{a\sigma}.$$

Inserting marginal costs for p_{ik} in the CES demand function yields the quantities of k-type timber shipped from i to j:

$$q_{ijk} = \left(\frac{p_{ik}\tau_{ijk}}{\theta_{ik}^{\gamma_{jk}}}\right)^{-\sigma} P_j^{\sigma-1}\vartheta_j Y_w = \left(c_i\tau_{ijk}\right)^{-\sigma}\theta_{ik}^{-\sigma\left(b-\gamma_{jk}\right)} P_j^{\sigma-1}\vartheta_j Y_w. \tag{1}$$

We assume that the expenditures on timber products in country j are a fraction ϑ_j of world expenditures for timber Y_w. $P_j = \left(\sum_{k=0}^{1}\sum_{h=1}^{J} n_h\theta_{hk}^{\sigma\gamma_{jk}}\left(\theta_{hk}^{b}c_h\tau_{ijk}\right)^{1-\sigma}\right)^{1/(1-\sigma)}$ is the CES price index normalised by 1 – (1/σ) and $\sigma > 1$ is the elasticity of substitution, which is constant and uniform across countries and timber types. $\tau_{ijk} > 1$ represents iceberg-type transportation costs. Following Hallak (2010), higher quality induced by sustainable production standards θ_{ik} is treated as a substitute for a price decrease so that the quality term $\theta_{ik}^{\gamma_{jk}}$ enters the demand function in the denominator. The effective impact of higher product quality additionally depends on the valuation of sustainable production standards and thus the willingness to pay for higher quality by consumers in each country j. Accordingly, γ_{jk} stands for the intensity of the country j's consumer preference for the quality of timber products of type k. Higher product quality induces higher prices as reflected by θ_{ik}^{b} in the price equation. The compliance with the sustainability standard of timber production as requested by the ITTA is assumed to affect the provision and the valuation of timber quality, increasing marginal costs of tropical timber production and shifting the demand curves to the right. The parameter $\sigma(b - \gamma_{jk})$ can be interpreted as the elasticity of quantities sold with respect to quality depending on the difference between the elasticity of marginal costs and elasticity of demand with respect to quality. This specification shows that the quantity of tropical and nontropical timber produced in i and sold in j ceteris paribus decreases in quality if $b > \gamma_{jk}$.[7]

The sales of a k-type timber firm located in country i and serving the market in country j can be written as:

$$s_{ijk} = \left(c_i\tau_{ijk}\right)^{1-\sigma}\theta_{ik}^{b-\sigma\left(b-\gamma_{jk}\right)} P_j^{\sigma-1}\vartheta_j Y_w. \tag{2}$$

Quality will exert a positive impact on sales if $\gamma_{jk} > b - (b/\sigma)$. In this case, the price increase is larger than the reduction in the quantity of k-type timber sold as a response to an increase in quality. If we do observe a positive impact of the ITTA on the value of trade flows, we can conclude that the consumers' quality evaluation γ_{jk} is high enough, so that the quality impact of the ITTA dominates its cost effects. In contrast, an increase in marginal costs, c_i, at given quality, always increases the price and reduces the quantity sold since demand is assumed to be elastic. In this case, sales will always be reduced.

Aggregating over importers (including the domestic market) yields the value of total production in country i as a share in world production, Y_w:

[7]One can show that $b - (b/\sigma) < \gamma_{jk} < (1 + b(\sigma - 1))/\sigma < b$, since $b > 1$, is a sufficient condition for an optimal supply of quality to exist. $b - (b/\sigma) < \gamma_{jk}$ guarantees positive marginal returns of quality, while $\gamma_{jk} < (1 + b(\sigma - 1))/\sigma$ assures that the second-order condition holds.

$$\kappa_i = \sum_{k=0}^{1}\sum_{j=1}^{J}\frac{n_i s_{ijk}}{Y_w} = c_i^{1-\sigma} n_i \underbrace{\sum_{k=0}^{1}\sum_{j=1}^{J}\tau_{ijk}^{1-\sigma}\theta_{ik}^{b-\sigma\left(b-\gamma_{jk}\right)}P_j^{\sigma-1}\vartheta_j}_{\Pi_i^{1-\sigma}}.$$

The equilibrium price effects induced by the ITTA are captured by the outward multilateral resistance term $\Pi_i^{1-\sigma}$. Following Anderson and van Wincoop (2003), market clearing, and thus the constraint that the value of exports (including domestic trade) adds up to the value of production, implicitly determines equilibrium prices c_i and, hence, outward multilateral resistances. Inserting the outward multilateral resistances $\Pi_i^{\sigma-1}$ in the price index yields the system of multilateral resistances:

$$P_j^{1-\sigma} = \sum_{k=0}^{1}\sum_{i=1}^{J}\tau_{ijk}^{1-\sigma}\theta_{ik}^{b-\sigma\left(b-\gamma_{jk}\right)}\kappa_i\Pi_i^{\sigma-1}, \tag{3}$$

$$\Pi_i^{1-\sigma} = \sum_{k=0}^{1}\sum_{j=1}^{J}\tau_{ijk}^{1-\sigma}\theta_{ik}^{b-\sigma\left(b-\gamma_{jk}\right)}\vartheta_j P_j^{\sigma-1}. \tag{4}$$

In compact form, the gravity equation for tropical and nontropical timber can then be written as:

$$X_{ijk} = Y_w\tau_{ijk}^{1-\sigma}\theta_{ik}^{b-\sigma\left(b-\gamma_{jk}\right)}\vartheta_j P_j^{\sigma-1}\kappa_i\Pi_i^{\sigma-1}. \tag{5}$$

3.2 | The difference-in-difference design

The crucial determinants of interest are the trading partners' ITTA status as well as their economic and resource endowments, which influence the demand and supply of the overall timber quality. Actually, the ITTA includes two treatments: countries sign the ITTA as producers or as consumers of tropical timber. The ITTA status of exporting and importing countries is coded in dummies D_i and D_j that take the value 1, if the country is an ITTA member as an exporter or as an importer, respectively. These two effects can be enhanced, if both trading partners acceded to the ITTA (i.e., $D_iD_j = 1$).

We establish a difference-in-difference design by interacting the ITTA status dummies with a dummy T_k that is coded as 1, if a trade flow refers to tropical timber and 0 otherwise. As the ITTA excludes non-tropical timber, the dummy T_k takes the role of time in the difference-in-difference design. We propose to use the difference between tropical and nontropical timber as an identification device as: (i) bilateral trade data on a global level for the HS codes that identify tropical timber are not available before the first ITTA in 1986;[8] (ii) the treatment variable (ITTA membership) is highly persistent over time in the sense, that just a handful of countries left the ITTA between 1986 and 2011, when the third revision entered into force; and (iii) the ITTA does not affect nontropical timber production and trade as it is explicitly stated in the ITTA rules.

In this design, country pairs are observed twice, namely with a tropical and a non-tropical timber trade flow. We observe the delivery of the baseline quality of both, tropical and non-tropical timber, that is solely determined by the overall exporting countries' resource quality q_i and the importing countries' preference for quality y_j, respectively. As Hallak (2010) shows, the interaction of these two terms, that is, q_iy_j, can be used to test the Linder hypothesis (Linder, 1961), which suggests that countries similar in q_i and y_j trade more likely and more intensively with each other.

[8]The SITC, as an alternative product classification scheme, would allow to examine a longer time period, but does not clearly distinguish between tropical and non-tropical timber in all product categories.

At $T_k = 1$, the control group of non-ITTA members, $D_i = 0$ and/or $D_j = 0$, trade baseline qualities for tropical timber as well, while ITTA members either commit themselves to higher and sustainable quality as producer or consumer of tropical timber. In this way, we are able to identify the impact of the ITTA on timber trade.

In order to determine the impact of the ITTA on the values of bilateral timber trade flows, we differentiate between two effects. First, by signing the ITTA ($D_j = 1$), an importing country reveals its higher preference for sustainable product quality of tropical timber as compared to non-sustainable tropical timber supplied by non-ITTA members. We refer to the higher preference for sustainable produced quality as the *environmental preference effect* of the ITTA and use the parametrisation $(\delta + \varphi T_k)D_j$. This parametrisation allows for country-specific preference effects that relate to both, tropical and non-tropical timber ($\delta\ D_j$), and additionally includes the impact of the ITTA on the preferences for sustainable tropical timber products via the interaction term $\varphi T_k D_j$. Second, if the exporting country signs the ITTA ($D_i = 1$), it commits itself to produce a higher quality by increasing its sustainability in tropical timber production. This defines the *product standard effect* with parametrisation $(\kappa + \varphi T_k)D_i$. κD_i captures overall differences in production standards between ITTA members and non-ITTA members while the interaction $\varphi T_k D_i$ identifies the impact of ITTA on sustainable tropical timber production. Preferences for the baseline quality at the importer and exporter side, respectively, are modelled as βy_j and αq_i. In addition, in our empirical specification we allow for a constant difference between the value of tropical and non-tropical timber trade flows, which is denoted by λ_k.

To sum up, the difference-in-difference design uses the following specification

$$\begin{aligned} b - \sigma\left(b - \gamma_{jk}\right)\ln(\theta_{ik}) &= \lambda_k + ((\delta + \phi T_k)D_j + \beta y_j)((\kappa + \varphi T_k)D_i + \alpha q_i) \\ &= \lambda_k + \delta\kappa D_j D_i + \beta\kappa D_i y_j + \alpha\delta D_j q_i + \alpha\beta y_j q_i \\ &\quad + \alpha\phi D_j q_i T_k + \beta\varphi D_i y_j T_k \\ &\quad + (\kappa\phi + \delta\varphi + \phi\varphi)D_j D_i T_k. \end{aligned}$$

Overall, we observe eight different combinations of product quality effects, which influence the trade in timber. Four of them are observed for trade in nontropical timber, which is not covered by the ITTA provisions. For four tropical timber trade combinations the ITTA provision are relevant.

Non-tropical $T_k = 0$	*ITTA status*
(a) $\alpha\beta q_i y_i$	if $D_i = 0, D_j = 0$
(b) $\alpha\beta q_i y_i + \alpha\delta q_i$	if $D_i = 0, D_j = 1$
(c) $\alpha\beta q_i y_i + \beta k y_j$	if $D_i = 1, D_j = 0$
(d) $\alpha\beta q_i y_i + \alpha\delta q_i + \beta k y_j + \delta k$	if $D_i = 1, D_j = 1$
Tropical $T_k = 1$	
(e) $\lambda_k + \alpha\beta q_i y_i$	if $D_i = 0, D_j = 0$
(f) $\lambda_k + \alpha\beta q_i y_i + \alpha\delta q_i + \alpha\phi q_i$	if $D_i = 0, D_j = 1$
(g) $\lambda_k + \alpha\beta q_i y_i + \beta k y_j + \beta\varphi_j$	if $D_i = 1, D_j = 0$
(h) $\lambda_k + \alpha\beta q_i y_i + \alpha\delta q_i + \beta k y_j + \delta k$ $+ \alpha\phi q_i + \beta\varphi_j + (k\phi + \delta\varphi + \phi\varphi)$	if $D_i = 1, D_j = 1$

To infer the impact of the ITTA, we first calculate the difference between tropical and non tropical timber trade flows for all four combinations of ITTA memberships. In turn, these differences may be compared with the proper control group that involves non-ITTA exporters, non-ITTA importers or both of them. Formally, the ITTA effects are identified by the interactions of T_k with $D_i y_j$, $D_j q_i$ and $D_i D_j$, and are determined by the difference-in-difference parameters $\alpha\varphi$ (environmental preference effect), $\beta\varphi$ (product standard effect) and $(\kappa\phi + \delta\varphi + \phi\varphi)$ (interaction effect), respectively. We expect all of them to be positive. To summarise, we consider the following scenarios:

$$\begin{array}{lll} \text{Preference Effect: setting counterfactually } Dj = 0 & & \\ \text{(f)-(e)-((b)-(a))} & \alpha\phi q_i & \text{if } D_i = 0 \\ \text{(h)-(g)-((d)-(c))} & \alpha\phi q_i + (k\phi + \delta\varphi + \phi\varphi) & \text{if } D_i = 1 \end{array}$$

$$\begin{array}{lll} \text{Product Standard Effect: setting counterfactually } D_i = 0 & & \\ \text{(g)-(e)-((c)-(a))} & \beta\varphi_j & \text{if } Dj = 0 \\ \text{(h)-(f)-((d)-(b))} & \beta\varphi_j + (k\phi + \delta\varphi + \phi\varphi) & \text{if } Dj = 1 \end{array}$$

In this difference-in-difference framework, the ITTA effects can be consistently estimated under a set of identifying assumptions (Lechner, 2010). First, we have to assume that in the absence of the ITTA, the baseline quality between tropical timber and non-tropical timber differs by a constant, λ_k, in all countries, which is equivalent to the common trend assumption. The baseline quality for tropical and non-tropical timber is determined by climate and soil differences at the point of origin, by the specific timber species basket in the producer country and by consumption preferences and production standards. Introducing the ITTA only affects the consumption preferences and production standards of tropical timber and, therefore, leaves non-tropical timber in general unaffected. This leads us to the conclusion that in our difference-in-difference setting, the assumption of a common trend is likely to hold.[9]

For identification, the stable unit treatment assumption requires that the control group, that is, non-ITTA countries, remains unaffected by the ITTA. In our setting, the stable unit treatment assumption is likely to be violated, since the establishment of the ITTA affects a large segment of the tropical timber market. Higher quality of tropical timber will simultaneously shift the marginal cost curve upwards and the demand curve for tropical timber to the right. Equilibrium requires that the aggregate value of production of each exporting country equals its aggregated shipments to all countries including itself, which induces an adjustment of the multilateral resistance terms. As can be seen from the CES demand function (s_{ijk}), a change in quality or costs of a specific country pair exerts a direct effect on the consumer price but also an indirect one, which is mirrored in the CES price index P_j. Therefore, all countries exporting to country j are influenced by the changes in this specific country pair. Moreover, the restrictions determined by the system of multilateral resistances imply changes in the exporter i's specific mill price, which in turn is relevant for all importers. This price change will involve substitution in two directions: on the one hand, between tropical and non-tropical timber and on the other hand between ITTA and non-ITTA tropical timber products. For this reason, one has to expect third-country effects of the ITTA. The structural

[9]The comparison of the time effects referring to treated and untreated country groups, before the treatment comes into effect, would give some evidence whether the common trend assumption is fulfilled. However, our difference-in-difference setting does not allow to compare the treated and untreated countries for multiple periods before and after the treatment. The reason is that in our case, both the treated and the untreated countries are observable only twice: for tropical and non-tropical timber trade.

gravity model is especially suited to control for these third country or indirect effects on timber trade by accounting for changes in multilateral resistances in the counterfactual scenario.

3.3 | Empirical specification and comparative static analysis

For the econometric estimation, we have to consider that many countries do not trade with each other. Countries may systematically select into the group of tropical timber exporters and will serve a foreign market, if it is profitable. To account for the endogenous selection, we end up with two equations upon which the econometric specification is based. The first equation refers to the value of timber exports of country i to country j of type k, X_{ijk} (see Equation 5).

$$\ln X_{ijk} = (1-\sigma)\ln\tau_{ijk} + \big(b - \sigma(b-\gamma_{jk})\big)\ln\theta_{ik} + (\sigma-1)\ln(P_j) + \ln\vartheta_j \\ +(\sigma-1)\ln(\Pi_i) + \ln\kappa_i + \ln Y_w \qquad \text{if } V_{ijk}=1 \text{ and 0 otherwise.} \tag{6}$$

Equation (6) indicates that the value of bilateral timber trade flows increases in the production of quality θ_{ik} if the valuation of the consumers relative to the costs of quality is sufficiently large ($\gamma_{jk} > b - b/\sigma$), in the importers' share of timber expenditures in world expenditures ϑ_j, in the value of the exporter's total production κ_i. Further, trade flows are positively affected by multilateral resistances P_j and Π_i, which reflect the average prices on the demand and supply side.[10] Finally, timber trade decreases the higher the transportation costs τ_{ijk}.

Due to fixed bilateral trading costs, trade flows can only be observed, if an indicator variable $V_{ijk}=1$, that is, if an exporter i serves the import market j with timber type k. This is modelled by the subsequent equation of selection into exporting timber (see Equation 7). Following the literature (Helpman, Melitz, & Rubinstein, 2008), we assume free entry of suppliers into the import markets at fixed costs, f_{ijk}, which drives profits in each import market down to zero in the long-run equilibrium. Based on the zero profit condition:

$$\frac{1}{\sigma}X_{ijk} = f_{ijk},$$

and under the assumption that exporter profits are separable across destination countries and timber type, one may define a latent variable (V^*_{ijk}) that captures the propensity of trading timber:

$$V^*_{ijk} = (1-\sigma)\ln\tau_{ijk} + \big(b-\sigma(b-\gamma_{jk})\big)\ln\theta_{ik} + (\sigma-1)\ln(P_j) + \ln\vartheta_j \\ + (\sigma-1)\ln(\Pi_i) + \ln\kappa_i + \ln Y_w - \ln\sigma - \ln\big(f_{ijk}\big). \tag{7}$$

This specification implies that timber exports of type k from i to j are more likely to be observed the lower the trade barriers τ_{ijk}, the lower the fixed trade costs f_{ijk}, the higher the demand for and supply of quality, θ_{ik}, the larger the average demand and supply prices P_j and Π_i, the larger the import markets ϑ_j and the larger the exporters' production κ_i. Concluding, participation in the ITTA and, hence, the production of and the preference for sustainable product quality, does not only influence the value of the trade flows (intensive margin), but also the decision of an exporter to serve a foreign market with timber at all (extensive margin).

The gravity model implies that the probability of exporting timber to a specific market depends on the size of that market and market-specific fixed costs. As a result, unobserved trade shocks at the intensive margin also affect the propensity to export to that market, that is, the extensive

[10] We do not model the multilateral resistance terms structurally as in Anderson and van Wincoop (2003). These are captured by the Mundlak terms defined below.

margin. Naturally, this implies that the disturbances of the outcome equation (intensive margin), as specified in Equation 6 and the selection equation (extensive margin), see Equation 7, are correlated, which induces biased parameter estimates in the outcome equation. This suggests applying a sample selection model as proposed in procedure 4.1.1 of Semykina and Wooldridge (2010) and discussed in Wooldridge (2002, p. 835). Similar to the cross-section sample selection model by Heckman (1976), they propose applying a two-step approach in a panel setting and additionally including exporter and importer-specific averages of all explanatory variables (Mundlak terms). The Mundlak terms capture importer and exporter-specific fixed effects and therefore eliminate cross-sectional importer and exporter variation. Lastly, the Mills ratio (denoted as λ_{ijk}) corrects for sample selection in the outcome equation. Following Semykina and Wooldridge (2010), it is based on separate probit equations for tropical and non-tropical timber.

To specify the econometric model, we subsume the set of explanatory variables of the *outcome* equation into the vector w_{ijk} with the corresponding parameter vector β. The right-hand side variables of the *selection* equation, z_{ijk}, include w_{ijk} plus additional explanatory variables.

Cameron and Trivedi (2005) show that the sample selection model, since it is non-linear, is formally identified without an exclusion restriction and precise estimation is possible, if the variation of z_{ijk} is large enough. However, adding an exclusion restriction is recommended, especially if the Mills ratio turns out to be highly collinear to the explanatory variables in the outcome equation. We use indicators of unobserved destination-specific fixed costs as additional explanatory variables in the selection equation.

Denoting the iid disturbances for each country pair by (ε_{ijk},η_{ijk}), the empirical specification of the panel sample selection model can be written as:

$$\ln V_{ijk}^{*} = z_{ijk}\gamma + \bar{z}_{i..}\xi_k + \bar{z}_{.j.}\zeta_k + \varepsilon_{ijk},$$

$$V_{ijk} = \begin{cases} 1, \text{if } V_{ijk}^{*} > 0 \\ 0, \text{if } V_{ijk}^{*} \leq 0, \end{cases}$$

$$\ln X_{ijk} = \begin{cases} w_{ijk}\beta + \bar{z}_{i..}\vartheta + \bar{z}_{.j.}\theta + \rho\lambda_{ijk} + \eta_{ijk}, \text{if } V_{ij}^{*} > 0 \\ \text{unobserved, if } V_{ijk}^{*} \leq 0, \end{cases}$$

$$\varepsilon_{ijk}, \eta_{ijk} \sim N_2(0, (1, \sigma_\varepsilon^2, \rho\sigma_\varepsilon)).$$

Although this model seems restrictive due to its distributional assumptions, it has the important advantage of allowing the derivation of theory consistent comparative statics. In our robustness exercise, we also use a semi-parametric estimation framework, which does not rely on a normality assumption. This approach is provided by Newey (2009) and Semykina and Wooldridge (2010).

Potential endogeneity of the ITTA treatments is not a serious problem in our bilateral gravity model setting. Most of the empirical work on the impact of international agreements, like the ITTA, on trade using instrumental variables involves cross-country variation ("between" estimation), not within-country variation across time ("within" estimation). We exploit "within" variation using Mundlak terms, which are equivalent to importer and exporter fixed effects. These Mundlak terms capture time invariant determinants of whether a country is, on average, more or less likely to accede to the ITTA. More importantly, an importing and exporting country's decision to accede to the ITTA is an unilateral one. This means that a country's ITTA membership does not refer to a specific bilateral relationship, but pictures a unilateral decision. Endogeneity is related to disturbances varying at the bilateral level, but there is no reason to assume that the country's unilateral decision is influenced by specific bilateral relationships. See Baier and Bergstrand (2007) and Glick and Taylor (2010) for a detailed discussion on this issue. Therefore, in our bilateral setting, a country's ITTA status can be seen as an exogenous decision as unobserved unilateral influences are captured by the inclusion of Mundlak terms.

3.3.1 | Comparative static analysis

In order to quantify the size and distribution of the impact of the ITTA on timber trade, we compare the predicted export flows in the baseline scenario with the counterfactual that assumes that the ITTA is not in force. Thereby, we concentrate on the intensive margin assuming that the decision to serve a foreign market with tropical timber at all remains largely unaffected by the ITTA.[11] Actually, the direct effect of the ITTA on the extensive margin is small. Setting the ITTA dummies to zero yields a reduction in the probability of exporting from 12.11% to 11.52%. This reduction by 0.59 percentage points exhibits a standard deviation of 1.6 percentage points. Hence, there is negligible evidence that the ITTA induces new trade relationships between countries by unlocking new markets to signatories. Another reason why we focus on the intensive margin in our comparative static analysis is the lack of clarity with respect to zero trade flows in our data. They comprise unreported trade flows, trade flows below the reporting threshold and true zeros.

To obtain an estimate of the causal impact of ITTA on the intensive margin of trade, we solve the structural gravity model with and without ITTA in force at given exporter status. We use the estimated parameters of the gravity model and explicitly allow for changes in the multilateral resistance terms.[12] Therefore, it is possible to estimate third-country effects, that is, the change in timber trade of countries that do not participate in ITTA. Note, since domestic trade flows are not included in the trade database, the comparative static analysis has to rely on out of sample predictions for both: the baseline and the counterfactual domestic trade flows scenario in order to establish a complete system of trade resistances. Following Yotov, Piermartini, Monteiro, and Larch (2016), we assume that there are no trade barriers within countries. Furthermore, we use the internal distances as defined in the CEPII database (Mayer & Zignago, 2011). All other explanatory variables are based on unilateral information and are thus observed for internal trade flows as well. Since domestic trade flows are assumed to be always positive, the corresponding value of the Mills ratio is set to zero. To sum up, the comparative static analysis of the ITTA proceeds in the following steps:

1. Estimate the panel Heckman sample selection model to obtain all parameter estimates.
2. Under the observed pattern of trade participation calculate the trade flows as $\widehat{x}_{ijk} = e^{w_{ijk}\widehat{\beta}+\widehat{\rho\lambda}_{ijk}+\mu_i+m_j}$, for $V^*_{ijk}>0$ and set it to zero, otherwise. μ_i is defined as $\ln(\kappa_i \Pi_i^{\sigma-1})$ and m_j as $\ln(\vartheta_j P_j^{\sigma-1})$. $\Pi_i^{\sigma-1}$ and $P_j^{\sigma-1}$ are derived as solution of the system of multilateral resistances *with* ITTA in force assuming that the endowments with tropical timber are given and that income spent on timber in each importing country is a fixed fraction of GDP.

[11]Including the extensive margin in the comparative static analysis would require to obtain counterfactual predictions on the indicator of positive bilateral exports. In turn, this would allow to solve the system of trade resistances under the counterfactual exporter status. Obtaining these predictions on the extensive margin is beyond the scope of the present analysis.

[12]We take the value of production (κ_i) and consumption (ϑ_j) in each country as given and solve for conditional equilibrium effects (Larch & Yotov, 2016).

3. Recalculate the predicted trade flows setting the ITTA parameters to zero to obtain $\widehat{x}_{ijk}^{c} = e^{w_{ijk}^{c}\widehat{\beta}+\rho\widehat{\lambda}_{ijk}^{c}+\mu_{i}^{c}+m_{j}^{c}}$. Solve the system of multilateral resistances *without* ITTA in force to get counterfactual multilateral resistance terms under the observed exporter status.
4. Calculate the difference in positive trade flows aggregated to country groups as weighted average percentage changes $100 \times \left(\widehat{x}_{ijk}/\widehat{x}_{ijk}^{c} - 1\right)$ using the counterfactual outcomes as weights.

4 | THE DATA

4.1 | Data description and modification

Information on the value of bilateral timber imports is taken from the United Nation's commodity trade statistic database. We refer to the Harmonized Commodity Description and Coding System 2007 which classifies logs, veneer sheets, sawnwood and plywood into 12 tropical subcategories and seven non-tropical complements (for a detailed definition, see Table A1 in the Appendix). To examine the trade effects of the ITTA, we focus on a time period of 5 years, starting in 2007 until 2011. Based on the fact that for some trading partners only a few observations per product class and year are available and that a country's ITTA membership in our sample is in general time invariant, we average our sample over time and only distinguish between tropical and non-tropical timber (instead of using the 6-digit classification).[13] The chosen period of observation is motivated by the fact that the 1994 agreement was superseded by a successor agreement, which entered into force on December 7, 2011. We restrict the time period over which we average to the five most recent years prior to the enforcement of ITTA's third revision in order to provide conservative estimates with respect to the extensive margin. Averages over a longer time frame would increase the number of positive trade flows.[14]

The ability to produce and to offer a higher baseline quality of timber may primarily be a matter of exogenous (natural) conditions. We capture the baseline quality of timber via the producer countries' average annual precipitation assuming that humid areas have a higher level of quality in timber production than arid regions (Sankaran et al. 2005; Staver, Archibald, & Levin, 2011; Wagner, Rossi, Stahl, Bonal, & Herault, 2012). Analogous to Hallak (2010), we use GDP/capita as indicator for the consumer's demand for quality. Data on the trading partners' average annual precipitation in depth (mm) and on their GDP/capita stem from the World Development Indicators compiled by the World Bank.

Geographical information (distance between the trading partners, common language, contiguity and colonial linkages) is taken from the CEPII database (Mayer & Zignago, 2011). Regional trade agreements (RTA) in force are taken from Baier, Bergstrand, Egger, and McLaughlin (2008) and from the World Trade Organization's Regional Trade Agreements Information System. To control for a potential confounder of the ITTA, we include a US Lacey Act dummy, which is 1 for all trade flows where the United States is an importer. We are not aware of other trade policy

[13]Since the ITTA is quite general in its overall objectives and suggested measures, we expect that the agreement affects the various tropical timber products similarly, so that the aggregation of the tropical timber classes is justified. The heterogeneity in characteristics between tropical and non-tropical timber could result in systematic differences in the respective import flows which we account for by including a tropical timber dummy in the econometric specification.

[14]To check whether our results are sensitive to the time period considered, we average our sample over three alternative time periods (years 2007–11 but leaving out 2009, years 2007–08 and years 2010–11) and apply a panel Heckman sample selection model for the respective sample. The coefficients for sustainable quality are in general similar to our base estimates with respect to sign, magnitude and significance level (results are available upon request).

measures, which explicitly affect tropical timber trade in the time period considered in our study and which could affect our estimates.

Our main independent variable of interest, the status of a country's ITTA membership, is defined through Annex A and Annex B of the 1994 International Tropical Timber Agreement (ITTA 1994). For the exclusion restriction, as described in Section 3.3, we use data on timber imports in the year 2000 to create a dummy variable indicating whether trading partners were already trading (non)tropical timber in 2000.[15] Further, following Helpman et al. (2008), we use an index for common religion as a proxy for cultural differences, which potentially influence the probability that two countries start to trade. Information on the percentage of a country's population that practice a given religion is taken from the World Religion Data, National Religion Dataset (Maoz & Henderson, 2013). Analogous to Johnson (2012), we use this information to construct a continuous variable, which represents the degree of common religion across country pairs. The higher it is, the larger is the share of residents in two countries that practice the same religion. Table A2 in the Appendix summarises and briefly describes the variables.

As the set of countries that trade timber may systematically differ from the countries that do not trade timber at all, we start with a sample of all exporting and importing countries that reported at least one bilateral timber trade flow. We drop exporters that are not tropical countries as they—by definition—cannot produce tropical timber (but rather represent intermediary trade partners). We are left with a sample of 123 importing and 80 exporting countries which are involved in trading timber in at least one of the subcategories listed in Table A1 in the Appendix. This results in 19,564 observations whereof about 13% (i.e., 2,604 observations) include information on timber trade, that is, imports in timber greater than 0. Out of the 2,604 bilateral trade flows, 2,007 (i.e., 77%) of them refer to trade in tropical timber.

4.2 | Descriptive statistics

Table 1 presents the descriptive statistics. The average value of timber imported amounts to 2,589,877 US$ per year. If we distinguish between imports in tropical and non-tropical timber, we find that the average value of tropical timber imported is substantially higher than the value of non-tropical timber imports (US$3,301,234 vs. US$198,429). In about 41% of all observations, at least one of the trading partners has signed the ITTA, and in 17% of the observations, the exporter as well as the importer is ITTA members.

Table 2 lists the 10 largest importers and exporters with respect to the aggregated (over the country's trading partners) value of imported tropical (upper panel) and non-tropical (lower panel) timber. All of the countries, which trade tropical timber, have signed the ITTA. Except Mauritania, Vietnam and Chile also the non-tropical timber traders are ITTA signatories.

The upper panel of Table 3 presents the trade flows of tropical timber in per cent of the total import value for each continent pair. About 40% of the total tropical timber trade occurs within Asia. Trade flows from Africa to Europe rank second but are considerably lower, namely 15%, which is followed by trade flows from Africa to Asia (11%), from Asia to Europe (9%) and from Asia to North America (7%). The remaining exporter–importer combinations are of minor relevance with respect to the value of imported tropical timber. Overall, Asia accounts for 55%, Europe for 27% and North America for 12% of the total import value of tropical timber. The largest

[15] We include the countries' trading status in the year 2002 (rather than 2000) to check whether the estimates are sensitive with respect to the starting period considered. We find that the selection as well as the outcome equation is insensitive to this alternative definition of the initial trading status. Results are available from the authors upon request.

exporters are Asia, Africa and South America, whose shares amount to 61%, 29% and 8%, respectively. The lower panel of Table 3 shows the average annual value of non-tropical timber trade flows of tropical timber exporters per continent in per cent of the import value of non-tropical timber. The total import value of non-tropical timber amounts to US$118 million, which is about 2% of the overall import value of tropical timber (US$6,626 million). With respect to the relative importance of each continent for non-tropical timber trade, we find that the export shares of Asia (67.49%), Africa (13.67%) and South America (9.06%) rank first, second and third—similar as for tropical timber trade though the percentages differ somewhat between the two types of timber. Regarding the role of importers, we find that Asia, Europe and Africa are the three major consumers of non-tropical timber.

Panel A of Table 4 compares the value as well as the number of tropical timber trade flows across countries that signed or did not sign the ITTA. The left-hand side panel shows that the group in which both trading partners signed the ITTA accounts for 85% of the total import value. Second rank the group of countries in which the exporter but not the importer is an ITTA member: The respective share in value of tropical timber trade flows is considerably lower at 10%. Comparing these percentages with the groups' shares in the total number of nonzero trade flows given in the right-hand side panel of Table 4 reveals that the number of trade flows are more balanced across the four groups.

Panel B of Table 4 presents on the left-hand side the trade flows in non-tropical timber per ITTA status of the importers/exporters in per cent of the total import value of non-tropical timber and on the right-hand side in per cent of the number of positive trade flows. We find the same patterns for

TABLE 1 Descriptive statistics

Variable	Obs.	Mean	*SD*	Min.	Max.
Imports in US$1,000	2,604	2,589.9	21,674.4	0.002	795,163.8
of which tropical	2,007	3,301.2	24,638.1	0.002	795,163.8
of which nontropical	597	198.4	1,080.6	0.007	21,370.4
QUAL (Exporter)					
Precipitation (in mm, exporter)	19,564	1,497.2	820.7	51.0	3,240.0
Forest rent (exporter)	19,320	4.4	6.6	0	34.6
GDP/capita (importer)	19,564	12,181.6	16,644.0	150.3	82,712.3
Distance (in km)	19,564	8,510.3	4,340.5	105.2	19,904.5
Contiguity	19,564	0.017	0.129	0	1
Common language	19,564	0.180	0.384	0	1
Colonial link	19,564	0.009	0.093	0	1
Common coloniser	19,564	0.099	0.298	0	1
Regional trade agreements	19,564	0.107	0.309	0	1
US Lacey Act	19,564	0.008	0.090	0	1
Religion	19,564	0.382	0.308	0	0.981
Trader2000	19,564	0.063	0.243	0	1
ITTA (importer)	19,564	0.406	0.491	0	1
ITTA (exporter)	19,564	0.412	0.492	0	1
ITTA (imp × exp)	19,564	0.166	0.372	0	1

TABLE 2 Largest importers and exporters of tropical and nontropical timber (ranked by average annual value imported[a])

Importers		Exporters	
Tropical timber trade			
Japan	1,336	Malaysia	2,116
China	862	Indonesia	1,077
United States	633	China	547
Republic of Korea	453	Cameroon	513
India	388	Gabon	490
France	378	Brazil	308
Netherlands	286	Congo	275
Italy	244	Ivory Coast	270
Belgium	214	Ghana	165
Germany	170	Ecuador	103
Nontropical timber trade			
Japan	24	China	60
United Kingdom	15	Australia	10
China	7	Malaysia	6
Ireland	7	Ivory Coast	6
Malaysia	5	Brazil	6
Mauritania	4	Indonesia	4
Thailand	4	Cameroon	3
Indonesia	4	Vietnam	3
India	3	Chile	2
Italy	3	Bolivia	2

[a]Sum of timber trade (in million US$).

non-tropical as for tropical timber trade although the trade shares of the trading pairs slightly differ across the types of timber. The comparison of the two panels of Table 4 further indicates that the value and the number of timber trade flows are considerably higher among ITTA partners than between countries where only one or none of the trading partners signed the ITTA. Panel C in Table 4 shows the distribution of total timber trade flows across the countries' ITTA status.

The right-hand side panel of Table 4 shows that we should have sufficient variation to identify the trade effect of the ITTA empirically. Note, that in our design, the type of timber (tropical vs. non-tropical) plays the role of the time dimension in a standard difference-in-difference framework, while the group of non-ITTA members form the control group. For estimating the environmental preference effect (i.e., $D_j = 1$), the control group consists of all the trade flows that refer to non-ITTA importers (41.90%). The treatment group comprises tropical timber trade flows of ITTA importers (56.55%). Analogously, for identifying the product standard effect ($D_i = 1$), the control group refers to trade flows of non-ITTA exporters (30.57%) and the treatment group captures tropical timber exports of ITTA members (68.01%).

TABLE 3 Trade flows in timber in % of import value

Exporter	Importer (1)	(2)	(3)	(4)	(5)	(6)	Total
Tropical timber, average annual import value: US$6,626 million							
(1) Africa	1.45	11.48	0.03	14.92	1.35	0.00	29.23
(2) Asia	1.79	40.57	1.52	9.42	7.32	0.10	60.72
(3) Australia	0.01	0.18	0.05	0.01	0.23	–	0.48
(4) Europe	–	–	–	–	–	–	–
(5) North America	0.00	0.99	0.00	0.06	0.27	0.00	1.33
(6) South America	0.04	1.92	0.04	2.77	3.25	0.23	8.24
Total	3.28	55.14	1.65	27.18	12.42	0.33	100.00
Nontropical timber, average annual import value: US$118 million							
(1) Africa	5.05	4.48	0.04	3.89	0.21	0.00	13.67
(2) Asia	2.16	35.71	1.05	27.84	0.74	0.00	67.49
(3) Australia	0.17	6.60	0.89	0.46	0.30	0.21	8.63
(4) Europe	–	–	–	–	–	–	–
(5) North America	0.03	0.76	0.00	0.19	0.16	0.01	1.14
(6) South America	0.29	3.44	0.22	2.42	2.44	0.25	9.06
Total	7.70	50.99	2.20	34.79	3.85	0.47	100.00

Notes. Figures are based on average annual bilateral trade flows in tropical and nontropical timber. "–" indicates that no bilateral trade flows in timber occurred between these continent groups in our sample of tropical exporters; "0.00" means that bilateral trade is of minor value (smaller than a 100th of a per cent).

5 | THE ESTIMATION RESULTS

The estimation results are based on the structural gravity model developed in Section 3.1. Column (1) of Table 5 shows the selection equation and Column (2) shows the outcome equation as defined in Section 3.3.

The significant Mills ratio, its interaction with tropical timber trade flows and the significant determinants in the selection equation point at the systematic selection of countries into the group of traders. The partners' initial trading status, which is used as an exclusion restriction, significantly influences the probability of timber trade. The second exclusion restriction variable, common religion between the country pairs, does not show a significant effect on the extensive margin. Further, the distance variables as proxies for trading costs influence the probability of trading timber as well as the value of trade flows as expected. The closer the countries are with respect to their location, their language and colonial links the more likely they trade with each other and the higher is their value of trade flows. The existence of a regional trade agreement between the trading partners significantly increases the probability of trading, but does not show an effect on the trade value. The US Lacey Act significantly affects the intensive margin of trade, but has no effect on the extensive margin.

The indicators for the baseline product quality component in Table 5 reveal that product quality matters and significantly impacts the extensive as well as the intensive margin of both, tropical and non-tropical timber trade. The probability of trading increases with a rise in baseline timber

TABLE 4 Trade flows in timber in % of import value and in % of the number of positive trade flows

Exporter	Import value[a] Importer (1)	(2)	Total	Nonzero trade flows[b] Importer (1)-	(2)	Total
Panel A: tropical timber						
(1) No ITTA	1.15	3.92	5.07	12.56	19.43	31.99
(2) ITTA	10.13	84.80	94.93	30.89	37.12	68.01
Total	11.28	88.72	100.00	43.45	56.55	100.00
Panel B: nontropical timber						
(1) No ITTA	2.76	7.40	10.16	9.05	16.75	25.80
(2) ITTA	15.31	74.53	89.84	27.64	46.57	74.20
Total	18.06	81.94	100.00	36.68	63.32	100.00
Panel C: tropical and nontropical timber						
(1) No ITTA	1.18	3.98	5.16	11.75	18.82	30.57
(2) ITTA	10.22	84.62	94.84	30.15	39.29	69.43
Total	11.40	88.60	100.00	41.90	58.10	100.00

Notes. Figures are based on the average annual bilateral trade flows in tropical (Panel A) and nontropical (Panel B) timber. Panel C comprises overall average annual trade flows in timber.

[a]The average annual import value amounts to US$6,626 million for tropical and US$118 million for nontropical timber, that is, US$6,744 million in total. [b]The total number of non-zero trade flows is 2,007 for tropical and 597 for nontropical timber, that is, 2,604 positive timber trade flows in total.

quality (captured via the Linder term) and with increasing consumers' preference for product quality. We do not find a significant impact of a country's capability to supply timber with high baseline quality on the extensive margin. With regard to the intensive margin, our results suggest that the consumers' higher preference for product quality significantly increases the value of trade flows, whereas the other two baseline quality indicators do not reveal a significant impact. The probability for positive trade flows as well as the trade values are higher for trading partners who both signed the ITTA which, similar to the Linder term, adds an additional bilateral baseline effect to the unilateral ones.

Concerning our parameters of interest—the indicators for the sustainable product quality component—we find an additional treatment effect for both, the consumers' environmental preference and the producers' capability to supply sustainable product quality for tropical timber, a theory consistent positive influence on the probability as well as the value of tropical timber trade flows. The coefficient on the interaction of the exporter's ITTA membership implies that at a given overall valuation of timber quality by the importers, as it is indicated by the importers' GDP/capita, ITTA producers have a higher probability as well as a higher value of tropical timber trade as compared to non-ITTA producers. The second interaction—the importer's ITTA status with the exporter's supply of a baseline tropical timber quality—reveals that exporters with the same baseline timber quality are more likely to trade with and export significantly more tropical timber to ITTA importers than to non-ITTA importers (for an analogous interpretation, see Hallak, 2010). However, we do not find a theory consistent bilateral ITTA effect on tropical timber trade in addition to the identified unilateral effects when both the exporter and the importer country joined the ITTA.

TABLE 5 Value of timber trade flows—estimation results

	Selection	(1)	Outcome	(2)
Sustainable quality ($T_k = 1$)				
Product standard effect:				
$\text{ITTA}_i \times \text{GDP}_j$	0.058***	(0.011)	0.077*	(0.040)
Environmental preference effect:				
$\text{ITTA}_j \times \text{QUAL}_i$	0.092***	(0.029)	0.216**	(0.097)
Enhancing interaction effect:				
$\text{ITTA}_i \times \text{ITTA}_j$	−0.338**	(0.138)	−0.330	(0.414)
Baseline quality				
$\text{ITTA}_i \times \text{GDP}_j$	0.078***	(0.022)	0.179***	(0.069)
$\text{ITTA}_j \times \text{QUAL}_i$	0.027	(0.046)	−0.209	(0.150)
$\text{ITTA}_i \times \text{ITTA}_j$	0.210*	(0.119)	0.669*	(0.372)
$\text{QUAL}_i \times \text{GDP}_j$ (Linder term)	0.096***	(0.013)	0.029	(0.047)
Controls				
Distance	−0.381***	(0.044)	−0.544***	(0.149)
Distance × T_k	−0.128***	(0.045)	0.053	(0.127)
Contiguity	0.418***	(0.106)	−0.407	(0.277)
Com language	0.189***	(0.055)	0.406**	(0.161)
Com colonizer	0.207***	(0.068)	0.379**	(0.169)
Colony	0.209	(0.143)	−0.178	(0.281)
RTA	0.169***	(0.054)	0.130	(0.143)
US Lacey Act	−0.149	(0.148)	0.882***	(0.250)
T_k	1.823***	(0.389)	1.717	(1.119)
Religion	−0.020	(0.079)		
Trader2000	0.884***	(0.056)		
Mills ratio			0.836***	(0.179)
Mills ratio × T_k			−0.888***	(0.164)
Observations	19,564		2,604	

Notes: Dep. Variable: log value of import flows.
*, **, *** indicate 10%, 5%, 1% significance levels. Constant and time averages of the exogenous variables (Mundlak, 1978) are not reported. Robust standard errors in parenthesis in selection equation. Bootstrapped standard errors in outcome equation.

To check the sensitivity of the baseline results, we conduct several robustness analyses. First, instead of using country-specific annual precipitation (see argumentation in Section 4), we include country-specific forest rents as an indicator for quality in timber production.[16] We thereby assume that producing higher quality is mirrored in higher forest rents. Panel A in Table A3 in the Appendix

[16]According to the definition given in the WDI, "forest rents are the harvest in roundwood times the product of average prices and a region-specific rental rate. The estimates of natural resources rents are calculated as the difference between the price of a commodity and the average cost of producing it."

reports the result of this robustness exercise focussing on the coefficients for sustainable product quality ($T_k = 1$). All in all, the robustness estimates support the findings of our base regression as they indicate that the major conclusions still hold. In particular, we still find evidence for a significant positive environmental preference effect once we replace the exporters' annual precipitation by the forest rent. The sustainable product quality effect significantly increases the probability of trading tropical timber, but is not precisely estimated regarding the value of timber trade flows.

The second robustness check refers to 1,044 trade flows where 522 country pairs trade both, tropical and non-tropical timber, to examine whether our main findings remain robust once we only use the identical control group for tropical as well as non-tropical timber trade flows. Panel B of Table A3 shows that even if we take the bilateral unobserved variables into account, we again find that ITTA consumers have higher preferences for sustainable tropical timber. Also, the sustainable product quality effect tends to positively influence tropical timber flows, but its impact is not significant.[17]

Third, we relax the assumption of normally distributed disturbances and apply a semiparametric estimation of the outcome equation. We re-estimate the outcome equation model using the two-step semiparametric series estimators introduced by Newey (2009) and replace the Mills ratio by splines with evenly spaced knots. Panel C of Table A3 highlights that the major results are also robust with respect to the normality assumption of the disturbances as we find similar estimates for the environmental preference and sustainable product quality effects regarding sign and magnitude as in the base specification.

Fourth, we use a median regression analysis for the outcome equation in order to account for the presence of outliers. The estimates are presented in Panel D of Table A3 in the Appendix. Our findings with respect to the coefficients for sustainable quality ($T_k = 1$) stay robust and indicate higher trade values for ITTA signatories with higher environmental preferences for and higher product standards of tropical timber.

5.1 | The impact of ITTA on different country groups

5.1.1 | The size of the sustainable product quality effect

The econometric estimates indicate that the sustainable product quality component significantly determines the value of tropical timber trade flows between member countries. In order to determine the size of this trade effect, we create a counterfactual that represents a world in which neither the exporter nor the importer is an ITTA member. The first state pictures the product standard effect and the second the environmental preference effect. Referring to the estimates reported in Table 5, we predict the import value in tropical timber for the country's observed ITTA status and compare these values with the respective counterfactual figures. These predictions are based on the procedure introduced in Section 3.3.1. Specifically, the difference in the value of timber trade flows between the observed situation and the counterfactual is measured as percentage change relative to the counterfactual status (i.e., non-existence of ITTA memberships on the exporter or importer side) and is split into a direct trade effect and a total trade effect. The direct trade effect holds the relative mill prices and therefore the multilateral resistance terms constant. It can be

[17]The insignificant coefficients in the selection equation result from the smaller treatment group involved in the balanced difference-in-difference sample which also defines the sample of positive trade flows. Only the 522 country pairs trading tropical and non-tropical timber belong to the sample of positive trade flows while the pairs trading only one of the two timber types are coded as zero trade flows.

TABLE 6 Counterfactual analysis—mean changes (in %) in tropical timber trade

		Product standard effect		
Exporter	Trade effects	N-ITTA Imp.	ITTA Imp.	Total
N-ITTA Exp.	Direct effect	0.00	0.00	0.00
	Total effect	−0.19	−6.39	−5.96
ITTA Exp.	Direct effect	93.21	103.96	102.99
	Total effect	9.31	5.47	5.81

Notes. Partial equilibrium effects of ITTA on tropical timber trade. Figures represent weighted average changes (see Section 3.3.1) in % comparing the observed status where some exporters are ITTA signatories with the counterfactual world where the ITTA is non-existent.

TABLE 7 Counterfactual analysis–mean changes (in %) in tropical timber trade

		Env. preference effect	
Exporter	Trade effects	N-ITTA Imp.	ITTA Imp.
N-ITTA Exp.	Direct effect	0.00	71.70
	Total effect	−6.95	6.55
ITTA Exp.	Direct effect	0.00	70.42
	Total effect	−7.14	3.41
Total	Direct effect	0.00	70.72
	Total effect	−7.10	4.15

Notes. Partial equilibrium effects of ITTA on tropical timber trade. Figures represent weighted average changes (see Section 3.3.1) in % comparing the observed status where some importers are ITTA signatories with the counterfactual world where the ITTA is non-existent.

interpreted as an upper bound of the ITTA effect. In contrast, the total effect allows for changes in exporter- and importer-specific multilateral resistances (indirect effects) as introduced in Anderson and van Wincoop (2003) in addition to the direct effects. As a consequence, non-ITTA members are indirectly affected by an introduction of the ITTA.

Tables 6 and 7 show the direct and total mean changes in the value of tropical timber trade due to the countries' ITTA membership. The product standard effect is identified, if the exporter joins the ITTA but the importer does not and the trade flow refers to tropical timber. On the other hand, if the importer accedes to the ITTA but the exporter does not and the trade flow refers to tropical timber, the estimated model reveals the environmental preference effect.

Starting with the product standard effect, as shown in Table 6, we find that exporters signing the ITTA experience a substantial increase in the value of tropical timber trade. Considering the direct effect, exporters who change to sustainably produced tropical timber can double their export values. However, the induced changes in multilateral resistance terms dampen this increase, so that the total trade effects level off at an increase in trade values of around 6%. The results for non-ITTA exporters reveal that even if no direct trade effect occurs (they are non-ITTA signatories in the actual and counterfactual world), indirect price effects induce negative trade effects, in particular when shipping tropical timber to ITTA importers. This negative product standard effect indicates that non-ITTA producer countries lose market shares, especially if importer countries are ITTA signatories.

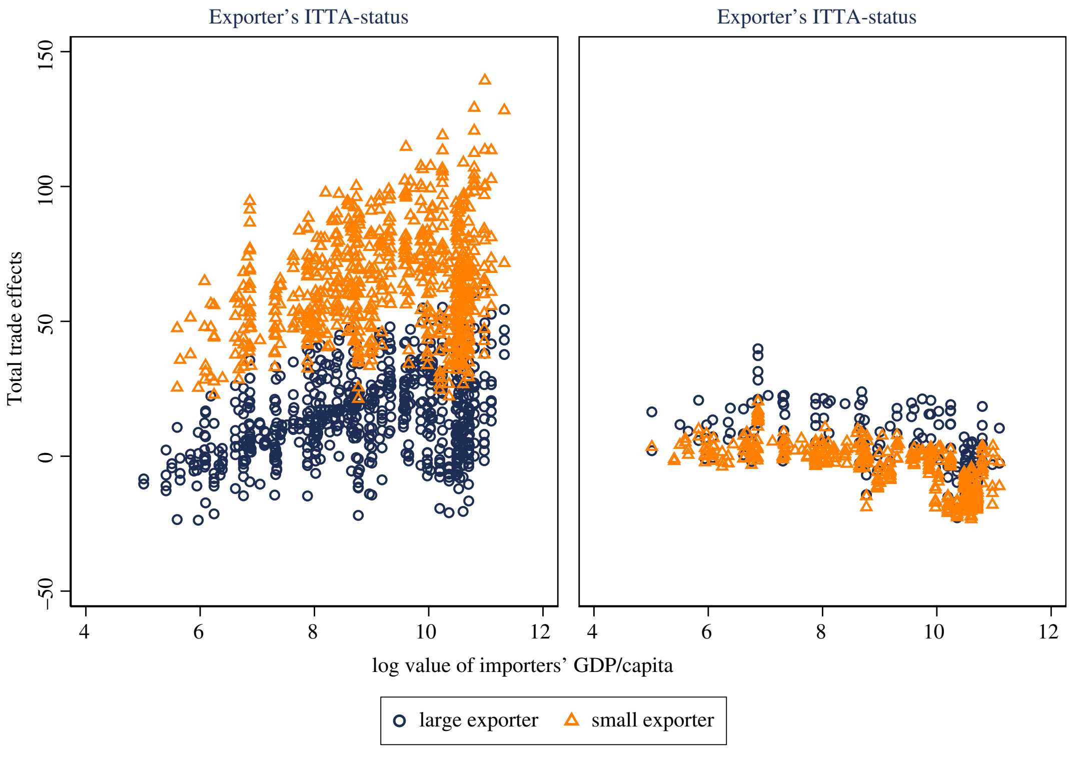

FIGURE 1 Total trade effects for International Tropical Timber Agreement (ITTA) and non-ITTA exporters (product standard effect)]

Table 7 shows the effect, when an importing country states a higher demand for sustainably produced tropical timber, which leads to a considerable increase in the value of tropical timber trade. The direct trade effect for ITTA importers indicates an increase in the value of tropical timber imports of around 71%. When we take the indirect price effects into account, the total increase in trade values for ITTA importers amounts to approximately 4%. Trade values for importers, who did not sign the ITTA, are reduced by about 7%. This negative environmental preference effect implies that non-ITTA importers tend to reduce their demand for tropical timber and switch to cheaper sources.

5.1.2 | The distribution of the sustainable product quality effect

An advantage of our empirical approach is that we are able to calculate the trade impact of an ITTA-induced change to sustainably produced tropical timber for every country in our sample separately. This allows for an alternative and more detailed way of examining the ITTA's impact on the trade patterns of tropical timber.

Figure 1 pictures the variation of the product standard effect per country. It focuses on the total trade effects and distinguishes between the ITTA status and the size of the exporter. We define small exporters as countries, whose forest rent (measured in US$) lies below the 75 percentile in the sample. The left-hand side panel of the graph nicely highlights that, in particular, small exporters benefit from a change to sustainably produced tropical timber as they experience a substantial

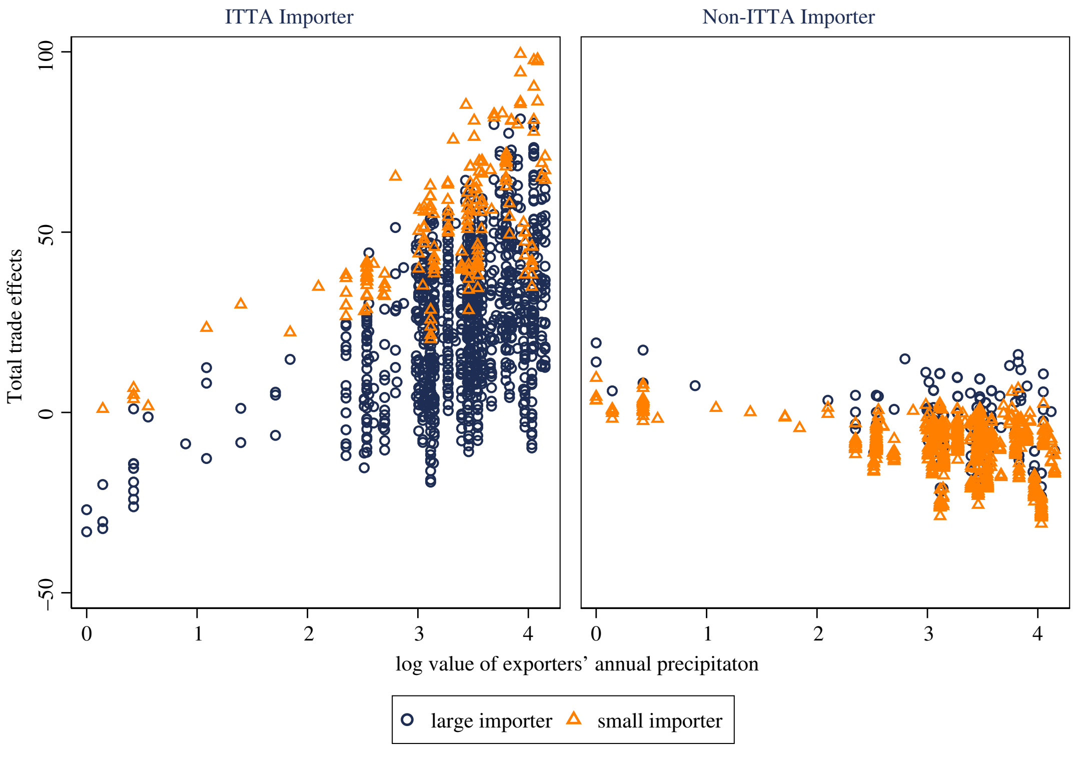

FIGURE 2 Total trade effects of International Tropical Timber Agreement (ITTA) and non-ITTA importers (environmental preference effect)]

increase in the value of tropical timber exports ranging from 21.25% to 139.28%. For the large exporters, the effect of a change to sustainably produced tropical timber is smaller and ranges from −23.27% to 63.43%. The right-hand side panel shows that even the non-ITTA countries are affected by the ITTA-induced changes in multilateral prices: Particularly, small non-ITTA exporters are confronted with reduced tropical timber flows.

For the environmental preference effect, we find similar patterns as for the product standard effect. Figure 2 pictures the environmental preference effect per importers' ITTA status and size. Small importers are defined as countries for which their GDP (in constant US$) lies below the 75 percentile. Again, small ITTA importers are the ones which experience the largest trade effect from a commitment to sustainably produced tropical timber (see left-hand side panel). Their import values in tropical timber rise by 0.98% to 99.43% which is more pronounced than the change in tropical timber trade values of the large importers ranging from −33.09% to 81.41%. For non-ITTA importers, we again find that particularly small importing countries experience a decrease in the value of tropical timber imports due to the ITTA.[18]

[18]To get an alternative overview of the trade effect of an ITTA-induced change in sustainable product quality, we plot the results of the counterfactual analysis for each country on a world map. In Figure A1 we show the total changes in the value of exports (aggregating over importer countries) if a group of exporting countries switch to sustainably produced tropical timber. Figure A2 shows the total change in the value of tropical timber trade flows for all import markets (aggregated over exporter countries) if a group of consumers reveal higher preferences for sustainably produced tropical timber.

6 | CONCLUSION

This paper addresses the impact of sustainability in production on international trade. In particular, it examines the effect of the International Tropical Timber Agreement on countries' trade patterns of tropical timber.

We find that a sustainable product quality matters and plays a central role in forming international trade patterns of tropical timber. The consumers' environmental preference as well as the producers' capability to supply sustainable product quality show a theory consistent positive and significant influence on the probability as well as on the value of tropical timber trade. The counterfactual analysis reveals that the total trade effects are clearly positive for ITTA signatories, which is in line with the findings of Houghton and Naughton (2017). Exporters as well as importers can considerably increase their value of tropical timber trade flows by either increasing their sustainable tropical timber production or by committing themselves to consume more sustainably produced tropical timber. Even taking indirect price effects into account, ITTA-exporting countries are able to increase their export values by about 6%. As for ITTA importers, their trade values in tropical timber increase by around 4%. Because the introduction of the ITTA changes the relative timber prices, third countries are also affected. The results for non-ITTA exporters reveal that they experience a reduction in trade values by about 6%–7%. The trade impact of an ITTA-induced change to sustainably produced tropical timber is not homogenously distributed in our sample. We analyse these country-specific ITTA impacts for each country in our sample, which includes ITTA as well as non-ITTA countries. Our results show that especially small countries can benefit from a change to sustainably produced tropical timber.

Given our model set-up, the increase in the value of tropical timber trade flows implies that the ITTA can also be seen as an effective environmental policy, which leads to lower harvest rates in tropical timber. This follows from the consequence that higher production costs induced by the ITTA results in higher prices for the signatory countries as compared to the control group of non-ITTA signatories. Given a price elastic demand for tropical timber, higher prices lead to a lower consumption level. Therefore, the higher trade values induced by the ITTA indicate that a lower amount of tropical timber is traded at higher prices. This leads us to conclude that consumers have a higher willingness to pay for sustainably produced tropical timber (Hallak & Schott, 2011).

It has to be noted that this study implicitly assumes that the level of compliance with the ITTA obligations is homogenously distributed among the member countries, since the level of compliance remains unobserved. More detailed information on the countries' implementation of sustainable production methods induced by the ITTA would allow to control for heterogeneity in compliance resulting, for example, from differences in the regulatory and institutional capacities or strategic decisions of countries. This issue would be an insightful future research question.

Although the ITTA is based on voluntary behaviour, the insights of this analysis are highly relevant in the light of the amendment of the US Lacey Act in 2008 and the recently introduced EU Timber Regulation, which entered into force in March 2013.[19] The EU Timber Regulation prohibits the placing of illegally harvested timber and timber products on the EU market. Countries importing or operating in the EU must exercise a high degree of due diligence and transparency in their production processes. Our results provide first evidence that such programmes may indeed be successful in supporting trade flows in high quality and sustainably produced tropical timber products.

We are convinced that the proposed model and the empirical strategy for estimating the trade effects of the ITTA contribute to a better understanding of how environmental policies can affect the production processes and their valuation by the consumers. Finally, even if the subject of our

[19]Regulation (EU) No. 995/2010 entered into force on 03/03/2013.

analysis, that is, tropical timber trade, is very specified, our approach can be more broadly used to determine the quality impact of international agreements, for example, product standard agreements, on international trade.

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APPENDIX

TABLE A1 Harmonized Commodity Description and Coding System 2007 (HS2007)

Code	Description		
Wood and articles of wood; Wood charcoal; Cork and articles of cork; Manufactures of straw, Of esparto or of other plaiting materials; Basketware and wickerwork			
44	Wood and Articles of Wood; Wood Charcoal		
4403	Wood in the rough, whether or not stripped of bark or sapwood, or roughly squared		
Tropical timber		Nontropical timber	
440341	Dark red meranti, light red meranti and meranti bakau	440391	Of oak (*Quercus* spp.)
440349	Other	440392	Of beech (*Fagus* spp.)
4407	Wood sawn or chipped lengthwise, sliced or peeled, whether or not planed, sanded or end-jointed, of a thickness exceeding 6 mm		
Tropical timber		Nontropical timber	
440721	Mahogany (*Swietenia* spp.)	440791	Of oak (*Quercus* spp.)
440722	Virola, imbuia and balsa	440792	Of beech (*Fagus* spp.)
440725	Dark red meranti, light red meranti and meranti bakau	440793	Of maple (*Acer* spp.)
440726	White lauan, white meranti, white seraya, yellow meranti and alan	440794	Of cherry (*Prunus* spp.)
440727	Sapelli	440795	Of ash (*Fraxinus* spp.)
440728	Iroko		
440729	Other		
4408	Sheets for veneering (including those obtained by slicing laminated wood), for plywood or for similar laminated wood and other wood, sawn lengthwise, sliced or peeled, whether or not planed, sanded, spliced or end-jointed, of a thickness not exceeding 6 mm		
	Tropical timber		
440831	Dark red meranti, light red meranti and meranti bakau		
440839	Other		
4412	Plywood, veneered panels and similar laminated wood Plywood, consisting solely of sheets of wood (other than bamboo), each ply not exceeding 6 mm thickness		
	Tropical timber		
441231	With at least one outer ply of tropical wood		

TABLE A2 Variable description and sources

Variable	Description	Source
Dependent variables		
X_{ijk}	Import value (in 1,000 US$) of tropical ($k = 1$) and nontropical ($k = 0$) timber products from exporter i to importer j	UN Comtrade
V_{ijk}	Dummy variable = 1 if value of bilateral trade flow of tropical or nontropical timber products from exporter i to importer $j > 0$, 0 otherwise	
Independent variables		
$Colony_{ij}$	Dummy variable = 1 if the two trading partners have ever had a colonial link, 0 otherwise	CEPII
$Com\ colonizer_{ij}$	Dummy variable = 1 if the two trading partners have had a common coloniser after 1945, 0 otherwise	CEPII
$Com\ language_{ij}$	Dummy variable = 1 if the two trading partners share the same language, 0 otherwise	CEPII
$Contiguity_{ij}$	Dummy variable = 1 if the two trading partners share a common border, 0 otherwise	CEPII
$Distance_{ij}$	Distance (in km) between the largest (most populated) cities of the two trading partners	CEPII
GDP_j	Importer's GDP per capita in constant year 2000 US$	World Bank, WDI
$ITTA_i$	Dummy variable = 1 if exporter is ITTA member, 0 otherwise	Annex A and B of ITTA (1994)
$ITTA_j$	Dummy variable = 1 if importer is ITTA member, 0 otherwise	Annex A and B of ITTA (1994)
$ITTA_iITTA_j$	Dummy variable = 1 if both trading partners are ITTA members, 0 otherwise	Annex A and B of ITTA (1994)
$Linder_{ij}$	Interaction between the exporter's quality indicator of production and importer's GDP/capita, $QUAL_i \times GDP_j$	
RTA_{ij}	Dummy variable = 1 if a regional trade agreement between the two trading partners is in force, 0 otherwise	Baier et al. (2008); WTO
$US\ Lacey\ Act_j$	Dummy variable = 1 if importer is United States, 0 otherwise	
T_k	Dummy variable = 1 if trade flow refers to trade in tropical timber, 0 otherwise	
Quality parameter ($QUAL_i$)		
$Precipitation_i$	Average (over time and space) precipitation in depth (mm per year) in exporter country	World Bank, WDI
$Forest\ rent_i$	Roundwood harvest times the product of average prices and region-specific rental rate (in % of GDP)	World Bank, WDI
Exclusion restrictions		
$Religion_{ij}$	Proportion of residents in two countries that practice the same religion	World Religion Data
$Trader2000_{ijk}$	Dummy variable = 1 if two trading partners were timber traders in the year 2000, 0 otherwise	UN Comtrade

TABLE A3 Value of timber trade flows—robustness analyses

	Selection	(1)	Outcome	(2)
Panel A: Forest rent as proxy for high-quality timber production				
$ITTA_i \times GDP_j$	0.051***	(0.010)	0.042	(0.031)
$ITTA_j \times QUAL_i$	0.020**	(0.009)	0.052*	(0.029)
$ITTA_i \times ITTA_j$	−0.105	(0.099)	0.330	(0.255)
Observations	19,320		2,527	
Panel B: Balanced difference-in-difference sample				
$ITTA_i \times GDP_j$	−0.013	(0.014)	0.060	(0.047)
$ITTA_j \times QUAL_i$	−0.031	(0.039)	0.320***	(0.117)
$ITTA_i \times ITTA_j$	0.069	(0.174)	−0.437	(0.494)
Observations	19,564		1,044	
Panel C: Nonparametric estimates				
$ITTA_i \times GDP_j$	0.058***	(0.011)	0.056	(0.035)
$ITTA_j \times QUAL_i$	0.092***	(0.029)	0.211**	(0.098)
$ITTA_i \times ITTA_j$	−0.338**	(0.138)	−0.188	(0.398)
Observations	19,564		2,604	
Panel D: Median Regression for outlier correction				
$ITTA_i \times GDP_j$	0.058***	(0.011)	0.104**	(0.046)
$ITTA_j \times QUAL_i$	0.092***	(0.029)	0.232**	(0.102)
$ITTA_i \times ITTA_j$	−0.338**	(0.138)	−0.477	(0.429)
Observations	19,564		2,604	

Notes: Dep. Variable: log value of import flows.
*, **, *** indicate 10%, 5%, 1% significance levels. Only coefficients for sustainable quality ($T_k = 1$) reported. Robust standard errors in parenthesis in selection equation. Bootstrapped standard errors in outcome equation.

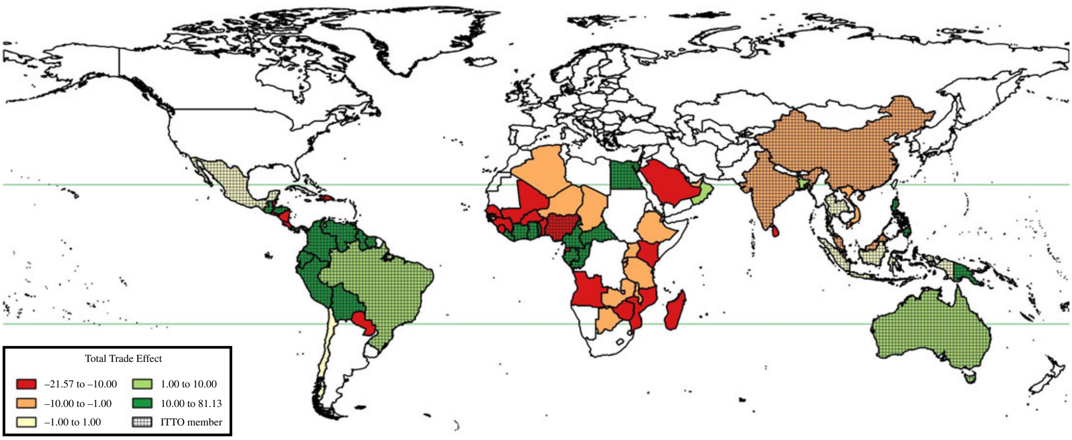

FIGURE A1 Total change in trade volume (product standard effect)
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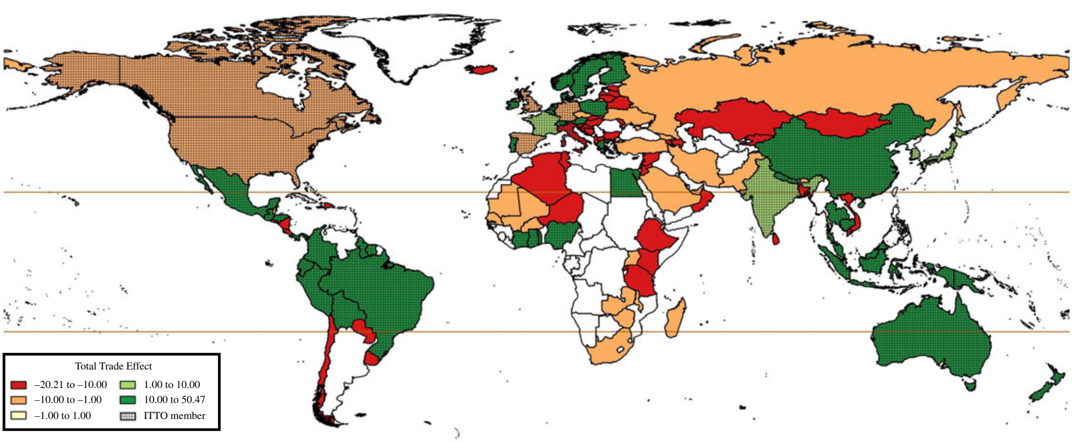

FIGURE A2 Total change in trade volume (environmental preference effect)
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