forests

MDPI

Article

The Structural Gravity Model and Its Implications on Global Forest Product Trade

Christian Morland *, Franziska Schier and Holger Weimar

Thuenen Institute of International Forestry and Forest Economics, Leuschnerstraße 91, 21031 Hamburg, Germany; franziska.schier@thuenen.de (F.S.); holger.weimar@thuenen.de (H.W.)

* Correspondence: christian.morland@thuenen.de; Tel.: +49-531-5965-111

Received: 30 December 2019; Accepted: 3 February 2020; Published: 5 February 2020

Abstract: The gravity model of trade is one of the most common approaches in modern econometrics. In its basic form, the model assumes that income and distance between two partners most likely play a major role in the occurrence of trade. Despite the long history of the gravity model and its high, universal explanatory potential, its application for the forest sector is not broad and refers only to the traditional definition of the gravity approach. However, this traditional approach is not able to explain all aspects of trade at a disaggregated sector level. Consequently, the present study aims to close this research gap and reveal influencing factors for the appearance and the intensity of forest product trade by applying the structural gravity approach. This is done via linear and non-linear estimation methods for the forest sector on the whole and for thirteen forest products in detail. Three major results were found: first, the traditional gravity approach overestimates the impact of the overall income on forest sector trade. Second, the appearance of wood market trade is not always influenced by the same factors as the quantity traded. Third, with increasing processing level, determinants of forest product trade seem to be influenced by different factors.

Keywords: Gravity model, wood markets, forest products, bilateral trade, PPML estimator

1. Introduction

In the complex network of international relationships, trade plays an important role for economic development, wealth and intercultural exchange. This is why the role of trade in the forestry and wood-based sector has already been analyzed in many ways, e.g., in context of the forest transition [1], illegal logging [2] or the network theory [3]. However, trade is no exogenous factor in the forestry sector; it is influenced by factors such as income, free trade agreements [4], shifting demand patterns [5] or domestic production [6]. A theory which fits all possible factors is not within reach but in 1962, Tinbergen introduced the gravity model of trade to explain international trade on the macro level [7].

The idea of trade gravity is borrowed from a basic principle of physics, where the mass of an object causes a force of attraction which diminishes with increasing distance; this force is called gravity. A similar effect can be observed in economics: the economic mass of both the domestic and the partner country attract trade while this effect is restrained by the distance between the potential trading partners. Since its first introduction, the gravity model is characterized by both a long history of applications across disciplines and by high empirical relevance [8]. However, while it gained attention in general economics, only few studies used the gravity model to describe bilateral trade in forestry and forest-based sectors. Some recent studies used this theory to explain trade flows with local focus for, e.g., agricultural exports of the USA [9], forest product trade relations between the EU member countries and Turkey [10], forest product trade between European countries [4] or trade in Chinese bamboo and rattan products [11]. To our knowledge only two studies used the model to analyze international wood market trade in the last 20 years on global level [12,13]. While Buongiorno [12] used only the gross domestic product (GDP) of the trading partners to describe bilateral trade flows and estimated it with linear panel methods, Larson et al. [13] additionally used the distance between partners and applied the Poisson pseudo maximum likelihood estimator (PPML), which is widely used in common gravity literature [14]. Although Larson et al. [13] mentioned that other indicators for wood market trade may exist, they did not include further variables in their study. However, these existing studies for gravity in wood markets generally used (i) the GDP as proxy for economic mass, which is usually positively related, and (ii) the distance, which is usually negatively related to trade and therefore refer to the traditional definition of the gravity model as described by Tinbergen in 1962 [7] or Anderson in 1979 [15]. Nevertheless, this traditional definition of gravity does only account for aggregated and not for sectoral or product specific trade. For analysis in the forest sector, this might be a problem because trade patterns differ across products, e.g., the magnitude of sawnwood trade depends highly on developments in the housing sector, particle board trade has a regional focus due to its weight, and newsprint trade drastically decline with increasing digitalization. The GDP as aggregated income may be a good proxy in aggregated trade analysis but if included in analysis for single forest sectors it may contain aggregation bias [16,17], if sector specific effects are ignored. Existing literature does not account for this effect and leaves a gap in the analysis of forest sector specific trade that the traditional gravity definition cannot close. However, the structural definition of gravity was developed to close such gaps by moving away from the intuitive traditional definition and explaining trade as a part in the total expenditures of an economy. Thus, it became able to explain trade on sector or product level and additionally give a broad economic background [16–18].

Consequently, the present study aims to analyze forest sector specific trade by applying the structural definition of gravity. The study aims to reveal the drivers that influence the likelihood of the occurrence and the magnitude of wood market trade by applying the structural gravity approach for the forest sector. For this aim, we first explain the structural gravity theory and outline how we apply this concept in an econometric design. In the following, we explain the database on which the estimation procedure is founded. Thereafter, the results are presented and discussed before we complete this study with a conclusion.

2. Materials and Methods

2.1. Methodology

The gravity model of trade may be derived as an analogy from physics, but developed further since its first introduction and became common knowledge in economics [19]. Approximately, in the last 10 years it became common to estimate gravity for forest sector specific trade [4,9–13]. However, existing literature for gravity in wood markets refer only to the traditional definition of the gravity model. According to this traditional definition, the specific trade flow (X) from the exporter j to importer n is influenced by the overall domestic income (Y) and bilateral accessibility (Φ) between partners. Bilateral accessibility describes time-invariant characteristics of a country pair such as distance or sharing the same language.

$$\boldsymbol{X_{nj} = Y_j{}^a \times Y_n{}^b \times \varphi_{nj}} \quad (1)$$

The multiplicative form of Equation 1 results from the physical analogy and is suitable to be estimated in log-log form with bilateral country fixed effects. Even though this model was successful in the explanation of aggregated trade, for the analysis of sector or product specific trade this traditional outline is too general [16–18]. Sector or product specific effects cannot be matched solely by the aggregated domestic income. Therefore, the gravity model was developed further into its structural definition. This definition also aims to identify drivers of the specific trade flow ($\boldsymbol{X_{nj}}$). Apart from material flow, trade can also be described by the flow of money. This expenditure from n to j for a specific product can be seen as a share ($\boldsymbol{\pi_{nj}}$) of the total expenditures in country n ($\mathbf{X_n}$):

$$\boldsymbol{X_{nj} = \pi_{nj} X_n} \quad (2)$$

The main issue in the context of structural gravity is to explain the share of total domestic expenditures to a specific trade flow. Through steps of transformation (see appendix or [18]), Equation 2 leads to Equation 3. Here, the import in country n is explained by the total production in country j ($\mathbf{Y_j}$), an index of market potential in j ($\mathbf{\Omega_j}$), the degree of competition in that market ($\mathbf{\Phi_n}$), and bilateral accessibility ($\boldsymbol{\varphi}_{\mathbf{nj}}$). While the index of market potential covers the maximal possible sales from j in the world (and in domestic market), the degree of competition captures the sum of all export capabilities (and domestic production) to n:

$$X_{nj} = \frac{Y_j}{\Omega_j}\frac{X_n}{\Phi_n}\varphi_{nj} \quad (3)$$

Equation 3 covers this structural definition of gravity and explains why income plays such an important role for bilateral trade in aggregated markets:

"At the aggregate level one should measure Y_j as gross production (not value-added) of traded goods (assuming X_{nj} is merchandise trade) and X_n should be apparent consumption of goods (production plus imports minus exports). However, in practice GDP is often used as a proxy for both Y_j and X_n" [18] *(p. 138).*

For the sectoral specific application of the structural gravity, Y_j can be interpreted as the sectoral production in the exporting country and X_n as the sectoral consumption in the importing country. Again, bilateral accessibility ($\boldsymbol{\varphi}_{\mathbf{nj}}$) describes time-invariant characteristics of a country pair such as distance or sharing the same language. However, as $\mathbf{\Omega_j}$ and $\mathbf{\Phi_n}$ cover potential market developments, they are difficult to measure for an econometric ex post analysis. In order to reach an approximation for market potential ($\mathbf{\Omega_j}$), we assume that the sectoral consumption in the exporting country equals the maximum possible sales from j in the world (and in domestic markets) because consumption (defined as production – export + import) captures the domestic need of a product and therefore the potential to export to other countries. Furthermore, for the degree of competition ($\mathbf{\Phi_n}$), it is assumed that the capability to export to a certain country is dependent on the existing production in the importing country. Therefore, the degree of competition in this study will be established by the production in the importing country.

In the next step, we transfer this theoretical framework of gravity into econometric analysis by applying a simple ordinary least squares (OLS) regression with importer and exporter fixed effects [20]. This fixed-effects approach (FE) was chosen because bilateral trade data contain individual effects for importer as well as for exporter countries. A simple OLS, therefore, would be biased a priori by this individual heterogeneity. Since the gravity model is nonlinear and the FE is designed for linear problems Equation 2 has to be transformed in log-log form:

$$\mathbf{X_{nj} = Exp\big(ln\,\alpha + ln\,\beta_1 Y_j + ln\,\beta_2 X_n + ln\,\beta_3 \boldsymbol{\varphi}_{nj} + ln\,\beta_4 \Omega_j + ln\,\beta_5 \Phi_n\big)} \quad (4)$$

However, this log-log form can cause another problem: if heteroscedasticity is still persistent within the FE framework, the estimation would be biased, because of Jensen´s inequality E(ln Y) ≠ ln E(Y). For this reason, a Poisson pseudo-maximum likelihood estimator (PPML) with importer and exporter dummies is suggested to estimate gravity models [21]. The PPML estimation has the advantage that it can be estimated in nonlinear form and, in addition, still works if zeros entries (the non-existence of trade between single countries) are included in trade data. Especially the latter issue is problematic in the log-log form of FE:

"Since it is not possible to raise a number to any power and end up with zero, the log of zero is undefined, and zero-trade flows cannot be treated with logarithmic specifications. At the same time, they need to be dealt with since they are non-randomly distributed. They indicate absence of trade, hence suggesting that barriers to trade are prohibitive to allowing a particular trade relationship to take place at a given demand and supply" [8] (p. 82).

Additionally, it may be possible that the likelihood of the occurrence and the magnitude of trade have different backgrounds. This study separates both problems and tests whether PPML with zero trade flows and PPML without zero trade flows differ significantly. A significant difference in the results of these two approaches could hint at the possibility that the appearance of wood market trade and its intensity may be influenced by different factors. To test for the equality—or differences—of modelling results obtained with the two PPML approaches, we follow the approach of [22] with the null hypothesis (H^0) that the coefficients estimated with the two PPML models do not significantly differ. In case that the testingprocedure shows that the coefficients for the PPML estimations significantly differ, we applied a Maximum-Likelihood approach (ML) with importer and exporter dummies. This procedure is done because Larson et al. [13] found that it may be possible that a PPML with and without zero trade in the forest sector differ. However, such difference may be important in sector specific trade flows and could therefore be a crucial part in the estimation of gravity in forest sector. For this purpose, we applied ML estimation with the binary response variable, trade (1) or no trade (0). With this method, it is possible to interpret factors that influence only the likelihood of whether trade happens.

Summarizing our approach, we started with the estimation of FE, then we tested on the existence of heteroscedasticity and if it was found, we applied the PPML estimations. The PPML were applied for data with and without zeros in trade flows and the results of both estimations were compared with each other by applying the approach of [22] and—in case they differ—we used a ML model to explain the reason of the difference. All estimations in this whole approach control for time-varying effects by including time fixed effects.

2.2. Data

Regarding structural gravity theory, five main influencing variables can be listed in the context of bilateral trade in wood markets: the production value of the exporter, the value of expenditures in the importing country, the production capacity of the exporter, market competition in the importing country and the accessibility from exporting to importing markets. However, because these variables have almost no direct equivalent observation in global databases, the present study has to use proxies which fit in these categories. Therefore, we collect data from different sources to capture as many determinants of wood market trade as possible. The database of the Centre d'études prospectives et d'informations internationals (CEPII) identifies proxies for market accessibility [23,24]. The forestry databases of the Food and Agriculture Organization of the United Nations (FAO) are used to explain trade and production data for fourteen major wood products (an overall 'forest products' category, industrial roundwood, sawnwood, veneer sheets, plywood, fiberboard, wood pulp, newsprint, paper and paperboard, industrial roundwood coniferous, industrial roundwood tropical, industrial roundwood non-coniferous, sawnwood coniferous and sawnwood non-coniferous) [25,26]. Moreover, the World Development Indicators (WDI) provides data for income [27]. Altogether, the database we gathered contains 74 variables (see Table A1 in Appendix). However, choosing the most fitting variables for consistent analysis over 14 product groups is complex. We decided to group all variables in one of the five categories of the structural gravity approach (total expenditures, total production, market potential, degree of competition and bilateral accessibility) and applied FE estimations with various combinations of these five categories. We compared the results via adjusted R^2, the Akaike information criterion (AIC) and Bayesian information criterion (BIC) and found that some variables are more likely to be part of a good specified product specific model than other. These variables are displayed in Table 1. Even though these variables were not part of any of the most fitting product specific models, they were always important factors. Therefore, in the following we will show only results for the variables displayed in Table 1. As response variable, we chose the export over the import value because this is not biased by tariffs or other trade costs.

Table 1. Determinants of global wood market trade**.**

Name	Category	Unit	Source
Export Value	X_{nj}	current US$	[26]
GDP per capita (exporter)	Y_j	current US$	[27]

GDP per capita (importer)	X_n	current US$	[27]
Forest Rents (exporter)	Y_j	% of GDP	[27]
Forest Rents (importer)	X_n	% of GDP	[27]
Production (exporter)	Y_j	1 000 m³	[25]
Consumption (importer)	X_n	1 000 m³	[25]
Production (importer)	Φ_n	1 000 m³	[25]
Consumption (exporter)	Ω_j	1 000 m³	[25]
Distance between Capitals	ϕ_{nj}	km	[23,24]
Continuous Countries	ϕ_{nj}	binary	[23,24]
Same Official Language	ϕ_{nj}	binary	[23,24]
Free Trade Agreement	ϕ_{nj}	binary	[23,24]
One partner is an EU member	ϕ_{nj}	binary	[23,24]
Both partners are EU members	ϕ_{nj}	binary	[23,24]

In the following we will introduce the determinants of global wood market trade flows defined for the present study. First, total production in the exporting country should be positively related to trade. For this category we suggest three possible variables: GDP per capita, forests rents and the quantity of production in the exporting country. Here, the econometric approach for the forest sector differs from general structural gravity approaches. Although in a macro perspective gross domestic production equals GDP, in a sectoral perspective it does not. Here, the sectoral production is important. This sectoral production can be observed, e.g., by forest rents (in percentage of GDP taken from the WDI. The World Bank estimated it by using roundwood harvest times, the product of average prices and a region-specific rental rate [27]) or the specific production of a product. However, GDP per capita should not be ignored in this category because it could also be a proxy for, e.g., the sectoral production potential.

Second, total expenditures in the importing country can be determined by its GDP per capita, the related forests rents and the consumption of certain products. All variables in this category should also be positively related to trade.

Third, for the category 'market potential', we defined the consumption of a certain product in the exporting country as a proxy variable. Here, the consumption can be interpreted as the total demand of the product which would compete with supply for exports. If the domestic demand for a product is high, this should reduce exports. The overall production of a good in the importing country in this study will be used as proxy to cover the degree of competition in the importing country. This is done because the export to one country will always compete with the domestic production in the importing country. However, both the degree of competition in the exporting country and the market potential in the importing country are difficult to measure but should be negatively related to trade.

Fourth, market accessibility can by determined by distance, cultural similarities or trade politics between two countries. Distance can be measured between capitals, economic centers or some other geographic points. In this study we decide to use the distance between capitals as a measure for distance. However, this measure does not inform about direct borders. For example, the distance between Peking (China) and Moscow (Russia) is 5795 km, while the distance between Moscow and Berlin (Germany) is 1614 km [23], even though Germany and Russia do not share a border. It could be assumed that the closer the distance, the greater the chance that trade could occur between the partner countries. Nevertheless, Russian exports to China account for 12.4% of its total export value of wood products, while exports to Germany account for only 7.6% [28]. This effect, to some degree, can be explained by the difference in total GDP between Germany and China, but the direct border shared by Russia and China may also play a role. While trade between Germany and Russia has to cross a minimum of two borders (except for transports by sea or by plane), trade between Russia and China can take place directly at the shared border. Therefore, a parameter covering continuous countries should be included in the econometric specification of the gravity theory in addition to the mere distance. Cultural similarities and trade politics, such as sharing the same language, being members of the EU or other free trade agreements, could ease negotiations or bureaucracy, which, in turn, could also raise trade activities between countries. Thus, the present study includes dummy variables for contiguous countries, countries sharing the same language, being members of the EU, the existence of free trade agreements and the distance between the capital cities of two countries to explain the category market accessibility.

3. Results and Discussion

In the following, we will present the results of the structural gravity approach created in the present work. Therefore, we start with the product group 'forest products', which is the aggregate of all forest products. It is notably that for 'forest products', trade is positively dependent on the income of both partners, while it is negatively dependent on the distance between these partners (see Table 2). The traditional definition seems to hold even in the structural gravity environment. This result is independent from the underlying estimation method: FE, PPML with zero trade flows, PPML without zero trade flows and ML yield to the same finding. Notwithstanding, to test for the best estimation model, a Breusch-Pagan-test was conducted. This points to heteroscedasticity in the FE model and implicates that the PPML model should be preferred over the FE linear regression model. Following the approach of [22], we also found significant differences between PPML estimation with and without zero entries in the export value. However, the differences between the PPML models are small and the estimated coefficients behave similar in both models. The ML estimation then gives information about the reasons of the small differences between the PPML models: contrary to the magnitude of trade, the likelihood of the occurrence of trade is not influenced by forest rents of the exporting country. In contrast, the language in both partner countries is an important factor for the likelihood of the occurrence of trade, but not for the magnitude of trade. Finally, while the magnitude of trade is negatively dependent on the consumption in the exporting country, the likelihood of the occurrence of trade is positively dependent on it.

Table 2. Estimation results for the product group 'forest products'.

	ML			PPML[1]			PPML[2]			FE		
Constant	-6.104	(-0.32)	***	0.013	(-3.03)		-1.668	(-2.9)				
Forest Rents (exporter)	-0.018	(-0.01)		0.211	(-0.02)	***	0.193	(-0.02)	***	0.137	(-0.01)	***
Forest Rents (importer)	-0.053	(-0.01)	***	-0.085	(-0.03)	*	-0.117	(-0.03)	***	-0.044	(-0.01)	***
Production (exporter)	0.057	(-0.01)	***	0.835	(-0.06)	***	0.833	(-0.05)	***	0.128	(-0.01)	***
Production (importer)	0.013	(-0.01)		-0.015	(-0.01)		-0.008	(-0.01)		-0.01	(-0.01)	
Consumption (exporter)	0.284	(-0.02)	***	-0.335	(-0.05)	***	-0.321	(-0.04)	***	0.229	(-0.02)	***
Consumption (importer)	0.403	(-0.02)	***	0.516	(-0.03)	***	0.52	(-0.03)	***	0.413	(-0.02)	***
GDP per capita (exporter)	0.212	(-0.02)	***	0.254	(-0.02)	***	0.27	(-0.02)	***	0.418	(-0.02)	***
GDP per capita (importer)	0.257	(-0.02)	***	0.169	(-0.02)	***	0.181	(-0.02)	***	0.23	(-0.01)	***
Distance between Capitals	-1.177	(-0.01)	***	-0.747	(-0.01)	***	-0.758	(-0.01)	***	-1.429	(-0.01)	***
Continuous Countries	0.223	(-0.06)	***	0.742	(-0.02)	***	0.732	(-0.02)	***	0.595	(-0.04)	***
Same Official Language	0.64	(-0.03)	***	-0.038	(-0.02)		-0.031	(-0.02)		0.517	(-0.02)	***

Free Trade Agreement	0.225	(-0.03)	***	0.494	(-0.02)	***	0.518	(-0.02)	***	0.399	(-0.02)	***
one partner is EU member	-0.197	(-0.04)	***	-0.227	(-0.04)	***	-0.206	(-0.04)	***	0.006	(-0.03)	
both partners are EU member	0.719	(-0.12)	***	0.21	(-0.08)	**	0.209	(-0.08)	**	0.347	(-0.06)	***
N	148639			78893			148639			78893		
Pseudo R^2/ adj. R^2	0.449			0.886			0.886			0.647		

ML refers to maximum likelihood estimation, PPML to poisson pseudo-maximum likelihood estimator, and FE to two way fixed effects estimator; $PPML^1$ = PPML without zero-trade; $PPML^2$ = PPML with zero-trade; Standard errors in parentheses; ***, ** and * are significant at the 0.1%, 1% and 5% level, respectively.

As mentioned above, forests rents, consumption, and the GDP of importing countries can be interpreted as proxies for total import expenditures. Within the framework of structural gravity, this interpretation leads to the assumption that all three variables are positively correlated with trade. However, our results reveal that only the consumption of forest products and the GDP in importing countries show significant positive signs in estimations. In contrast, forest rents in importing countries are negatively significant. Together with the non-significant influence of production in importing countries, this leads to the conclusion that, contrary to theoretical classification above, forest rents in importing countries function similar to the degree of competition in the importing country. On the other hand, and within the framework of structural gravity, production, forest rents and the GDP in the exporting country can be interpreted as part of the production value of the exporter. These variables behave exactly as suggested above and, thus, influence trade in a positive way, based on our results. Furthermore, according to our results it seems that the consumption in exporting countries is a suitable proxy for the market potential of the exporter as it significantly influences the magnitude of trade in a negative way.

In reference to the bilateral market accessibility, we found evidence that it is determined by the distance, a common border and the existence of free trade agreements between trading partners. Results show that with increasing distance, both the magnitude and the likelihood of the occurrence of trade are significantly negatively influenced, while sharing a border increases both components of trade. In general, we found that free trade agreements have a significant positive effect on trade, too. Membership of the EU turns out to be a special case in the context of free trade agreements. We found that it is an advantage for trade activities only if both partners are member of the EU but a disadvantage if only one partner is an EU member. Sharing the same language only increases the likelihood of the occurrence of trade but not its magnitude and can therefore only partly be interpreted as a variable in our structural gravity model which eases market accessibility.

In the next step, more detailed results will be presented for all 13 individual products. For this purpose, we grouped the individual products into the groups ’industrial roundwood’, ’sawnwood’, ’veneer, plywood and fiberboard’ and ‘wood pulp, newsprint and paper and paperboards’. For all individual products, we conducted Breusch-Pagan Tests and subsequently the approach of Paternoster [22], but we always found that the FE contains heteroscedasticity and both PPML approaches differed significantly. Therefore, the following results will be presented only for the estimation methods ML and PPML without zero trade flows.

3.1. *Industrial Roundwood*

In contrast to other product groups, industrial roundwood trade is significantly less driven by economic dependencies (see table A2). Factors, such as domestic production or consumption, do not influence the trade of any of the four products of industrial roundwood (tropical, coniferous and non-coniferous, as well as the aggregate of all three products). However, in the case of aggregated industrial roundwood and coniferous industrial roundwood, the GDP of the exporting country influence the magnitude of trade significant negatively. For non-coniferous industrial roundwood, exporters' GDP has no significant impact on the magnitude of trade, but the occurrence of trade is significant less likely if the GDP of the exporter is high. Consequently, our results suggest that high income countries attract industrial roundwood from low income countries. The opposite effect can be observed for the tropical parts of industrial roundwood. Here, the magnitude of trade is significantly positively dependent on the income of the exporter and significantly negatively dependent of the importer's income. Another interesting result is that free trade agreements influence the magnitude of trade for non-coniferous and tropical industrial roundwood significantly negative. An explanation for such relationship may be that free trade agreements go along with harmonized regulations and decreasing levels of protectionism. Altogether, the structural gravity approach does not seem to be the best approach to explain trade in the industrial roundwood product group. Within this group, trade may be influenced by interrelations which were not subject of the present study. However, it is possible that these results can, to some degree, be explained by the raw material character of industrial roundwood.

3.2. Sawnwood

For the aggregated sawnwood product (coniferous plus non-coniferous), the GDP in the importing country is significantly positively related to the magnitude of trade (see Table A3). The GDP in the exporting country have no significant influence on the magnitude of trade. Contrarily, the likelihood of the occurrence of trade is dependent of GDP in both importing and exporting partner countries, based on the ML results. In contrast to industrial roundwood, here, all coefficients, except for sharing the same language and forest rents in the importing country, behave as the theory suggests. Interestingly, the likelihood of trade for the aggregated sawnwood is not significant influenced by the distance between partners. This interrelation is unique for all estimations in this study. However, the trade for both individual products, coniferous and non-coniferous sawnwood, behaves mostly as structural gravity theory suggested. However, it is contrary to the expectation that the income of exporting countries shows a significant negative influence on the magnitude of trade for non-coniferous sawnwood. As for non-coniferous industrial roundwood, an explanation for this effect might be that high-income countries attract non-coniferous sawnwood from low income countries

3.3. Veneer, Plywood and Fiberboard

Contrary to the trade of sawnwood, we found that the importers' GDPs do not influence the trade value of wood panels positively (see table A4). For plywood and fiberboard there is no significant influence and for veneer this interrelation is negative significant. However, most coefficients influence the magnitude of trade and the likelihood of its occurrence for the individual products of this product group in the way the structural gravity approach above suggested. Even though, the EU membership of only one partner is significant negatively related to the magnitude and also to the likelihood of the occurrence of fiberboard trade. However, the EU membership of both trade partners does not influence any kind of fiberboard trade.

3.4. Wood Pulp, Newsprint and Paper and Paperboards

For the product aggregate 'paper and paperboards', the income in the importing country is significantly negatively related to the magnitude of trade, while the income of the exporting country is significantly positively related to the magnitude of trade (see table A5). This implies that it is likely that countries with higher income export paper and paperboards to countries with lower income. The level of consumption, on the other hand, is significantly positively related to the magnitude of trade in both the importing and the exporting country, which implies that the demand for paper and paperboards in the exporting country does not restrict export quantities. For the product newsprint, the magnitude of trade is not significant influenced by the GDP of one trade partner. However, the occurrence of trade for this product significantly increases if the GDP in the exporting country is increasing. Eventually, instead of GDP, the domestic production seems to be the "economic mass" variable for newsprint trade. Here, the traditional gravity approach has fallen short in the past, since it aims to specify the driving variable, but failed because it only investigated GDP and distance as possible determinants. On the other hand, the traditional gravity approach holds for wood pulp trade, but can be expanded on by production and forest rents of the exporting country as well as the consumption of the importing country (all three are significant positive related to the magnitude of trade).

After the previous presentation of our results in general and in detail for 13 individual products, we compared the results for individual wood products with each other (results in Table A2–A5). In this regard, one of our main findings is that with increasing complexity in the manufacturing process trade is determined by varying factors. For industrial roundwood, e.g., we found that processing is noticeably less influenced by factors such as rents in the forest sector or free trade agreements compared to paper products. It also holds that, if one of the trade partners is an EU member, this is an advantage for trade with industrial roundwood, sawnwood and veneer, but it is a disadvantage for trade with paper products. However, if both partners are EU members, forest products trade is always increasing (except for wood pulp and newsprint, as in this case this variable does not influence trade).

In the last part of this chapter, we will compare the results of the present study, with previous studies. For that, we only use results estimated with similar methods and product categories. We found that in the structural gravity environment, the GDP effect seems to be smaller, as noted in previous studies (see Table 3). This conclusion holds for all GDP coefficients except for paper products where the GDP effect for the exporter is higher than the result suggested in [12,13]. Thus, we conclude that the traditional gravity approaches applied in the past may overestimate the impact of GDP on forest sector trade by not accounting for forest sector specific effects.

Table 3. Comparison of GDP effects from structural (own estimations) and traditional gravity (results from [12,13]).

Product	Variable	Traditional Gravity FE [12]	Structural Gravity FE	Traditional Gravity PPML[1] [13]	Structural Gravity PPML[1]
Wood	exporter GDP	0.44	-0.021		
	importer GDP	1.9***	0.297***		
Wood pulp	exporter GDP	1.63**	0.23***	0.685***	0.344***
	importer GDP	1.24**	0.22***	1.022***	0.499***
Paper	exporter GDP	0.24	0.72***	0.396***	0.411***
	importer GDP	1.04***	0.08***	0.767***	-0.074***
Sawnwood non – coniferous	exporter GDP			0.798***	0.289***
	importer GDP			0.846***	0.384***

PPML[1] = PPML with zero-trade; ***, ** and * are significant at the 1%, 5% and 10% level, respectively.

4. Conclusions

In the present study, we applied a structural gravity model to explain the occurrence and magnitude of trade between two countries. This approach goes beyond the framework of previous studies, which concentrated on the application of a more traditional approach of gravity. Summarizing, we found that this structural gravity approach offers a more detailed look about the factors that influence bilateral trade in this sector as the traditional gravity model could do. Simultaneously, it provides a broader theoretical background. Nevertheless, the GDP as an aggregated factor is still a powerful tool to explain bilateral trade in the forest sector. The question why such an aggregated factor influences forest sector specific trade cannot fully be clarified by this study and remains for further research. However, the present study shows that past studies, which used the traditional gravity definition, overestimates the aggregated GDP effect on forest sector trade. The structural gravity framework applied here, on the other hand, tries to explain parts of this general GDP effect by including forest-sector specific parameters such as domestic production, consumption or forest rents in the econometric analysis. Further research could aim to identify determinants of product specific trade which potentially explain the influence of aggregated parameters, such as GDP, in even more detail.

Another finding of this study is that trade of further processed wood products behave differently than trade for raw materials, e.g., while trade for industrial roundwood increases with lower incomes in the exporting country and higher incomes in the importing country, the reverse relationship can be found in paper and paperboards. This effect may be observed because wood processing industry are rather located in countries with higher income, while low income countries are more likely to export the raw materials.

Finally, this study aims to identify factors influencing both the likelihood and the magnitude of trade flows. We found that in most cases these determinants behave similarly for both trade characteristics. However, for some product groups, there is a significant difference between these characteristics. The consumption of the overall forest product category, for example, is positively related to the occurrence and negatively related to the magnitude of trade. Even more interesting is the fact that the occurrence of aggregated sawnwood trade is not determined by the distance between trade partners, while the magnitude of trade is negatively dependent on this distance. This effect does only hold for this aggregated sawnwood and not for coniferous or non-coniferous sawnwood, respectively, and may result from the issue that aggregated product trade response differently than disaggregated product trade to external characteristics. This should be kept in mind for further research.

Author Contributions: Conceptualization, C.M., F.S. and H.W.; Data curation, C.M.; Formal analysis, C.M.; Methodology, C.M. and F.S.; Supervision, H.W.; Writing—original draft, C.M.; Writing—review and editing, F.S. and H.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Federal Ministry of Education and Research, Germany, grant number 031B0232A.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix

This definition of structural gravity can be explained by the specific trade flow (X_{nj}), which is described as expenditure from n to j for a specific product. However, this expenditure is only a share (π_{nj}) of the total expenditures in country n (X_n):

$$\boldsymbol{X_{nj} = \pi_{nj} X_n} \quad (1)$$

The derivation of structural gravity starts by describing the share of total domestic expenditures to a specific trade flow:

$$\boldsymbol{\pi_{nj} = \frac{S_j \varphi_{nj}}{\Phi_n}} \quad (2)$$

Here, S_j capture the capability of j to export, φ_{nj} the bilateral accessibility and Φ_n the set of opportunities for consumers in n and therefore the sum of all export capabilities to n $\Phi_n = \sum_l S_l \varphi_{nl}$. Inserting Equation 6 in Equation 5 leads to:

$$\boldsymbol{X_{nj}} = \frac{\boldsymbol{S_j \varphi_{nj}}}{\boldsymbol{\Phi_n}} \boldsymbol{X_n} \tag{3}$$

The sum of all exports and the domestic production (X_{nn}) is defined as Y_j:

$$\boldsymbol{Y_j} = \sum_{l} \boldsymbol{X_{lj}} \tag{4}$$

Applying this accumulation for equation 7 leads to:

$$\boldsymbol{Y_j} = \boldsymbol{S_j} \sum_{l} \frac{\boldsymbol{\varphi_{lj}\, X_l}}{\boldsymbol{\Phi_l}} \tag{5}$$

Introducing Ω_j as an index for market potential which cover the maximal possible sales from j throughout the world $\Omega_j = \sum_l \frac{\varphi_{lj}\, X_{lj}}{\Phi_l}$ and inserting it into Equation 9 leads to:

$$\boldsymbol{S_j} = \frac{\boldsymbol{Y_j}}{\boldsymbol{\Omega_j}} \tag{6}$$

Inserting Equation 10 in Equation 7 leads to:

$$\boldsymbol{X_{nj}} = \frac{\boldsymbol{Y_j}}{\boldsymbol{\Omega_j}} \frac{\boldsymbol{X_n}}{\boldsymbol{\Phi_n}} \boldsymbol{\varphi_{nj}} \tag{7}$$

Equation 11 is then the resulting structural gravity estimation as described by [18].

Table 1. Total variable selection.

ID	Variable	Variable for Ex- and Importer	Source	ID	Variable	Variable for Ex- and Importer	Source
1	Export Value		[26]	40	Distance between Capitals		[23,24]
3	Consumption	Yes	[25]	41	Distance Weighted		[23,24]
5	Production	Yes	[25]	42	Distance Weighted (distwces)		[23,24]
7	Consumption of all forest products	Yes	[25]	44	donator of GSP	Yes	[23,24]
9	Export quantity of all forest products	Yes	[25]	45	Empire		[23,24]
11	Import quantity of all forest products	Yes	[25]	47	EU member	Yes	[23,24]
13	Production quantity of all forest products	Yes	[25]	48	Free Trade Agreement (WTO)		[23,24]
15	Deflated Agricultural Sector	Yes	[27]	50	GATT/WTO member	Yes	[23,24]
17	Forest Rents	Yes	[27]	52	Hegemon	Yes	[23,24]
19	Forest Area	Yes	[27]	53	Hours diff. between partners		[23,24]
21	Population	Yes	[27]	54	Independence date		[23,24]
23	Population density	Yes	[27]	56	legal system after transition	Yes	[23,24]
25	Area in sq. km	Yes	[23,24]	58	legal system before transition	Yes	[23,24]
26	Colony from		[23,24]	59	part of the same Country		[23,24]

27	Colony to		[23,24]	60	preferential trade area		[23,24]
28	Colony		[23,24]	62	report of changes in Rose data	Yes	[23,24]
29	Colony before 1945		[23,24]	63	Same Ethnical Language		[23,24]
30	Common Currency		[23,24]	64	Same Official Language		[23,24]
31	Common Religion		[23,24]	65	Sever		[23,24]
32	Continuous Countries		[23,24]	66	Sibling		[23,24]
34	Cost start-up procedures (% of GNI per cap.)	Yes	[23,24]	67	Sibling with Conflict		[23,24]
35	Current Colony		[23,24]	69	Procedures to register a business	Yes	[23,24]
36	Current Sibling		[23,24]	71	Time to start a business(days)	Yes	[23,24]
38	Days + Procs to start a business	Yes	[23,24]	73	trade between Africa, ACP and EU	Yes	[23,24]
39	Distance		[23,24]	74	War between partners		[23,24]

Table 2. Estimation results for the product group 'industrial roundwood'.

	Total Industrial Roundwood		**Conif. Industrial Roundwood**		**Trop. Industrial Roundwood**		**Non-Conif. Industrial Roundwood**	
	ML	**PPML[1]**	**ML**	**PPML[1]**	**ML**	**PPML[1]**	**ML**	**PPML[1]**
Constant	25.809 (−2620.8)	10.506 (−8.11)	−0.042 (−1.12)	9.054 (−46.06)	1.379 (−1.55)	19.698 (−240.71)	−0.759 (−0.52)	8.699 (−10.17)
Forest Rents (exporter)	−0.146 (−0.13)	0.171*** (−0.02)	−0.016 (−0.03)	0.324 (−0.26)	0.024 (−0.02)	0.164** (−0.06)	−0.066** (−0.02)	0.078* (−0.04)
Forest Rents (importer)	−0.026 (−0.06)	0.085 (−0.15)	−0.019 (−0.03)	0.144 (−0.46)	−0.125* (−0.05)	0.348 (−0.4)	−0.078** (−0.03)	0.204 (−0.24)
GDP per capita (exporter)	−0.299* (−0.13)	−0.279*** (−0.06)	−0.074 (−0.04)	−0.644*** (−0.13)	−0.201*** (−0.04)	0.936** (−0.32)	−0.116*** (−0.03)	0.158 (−0.09)
GDP per capita (importer)	−0.28* (−0.14)	0.856*** (−0.05)	0.535*** (−0.05)	1.341*** (−0.12)	0.46*** (−0.05)	−0.527* (−0.23)	0.381*** (−0.04)	0.646*** (−0.09)
Distance between Capitals	−0.486*** (−0.08)	−1.152*** (−0.05)	−1.145*** (−0.03)	−1.196*** (−0.12)	−0.587*** (−0.03)	−1.369*** (−0.34)	−0.907*** (−0.02)	−1.253*** (−0.07)
Continuous Countries	0.189 (−0.2)	1.677*** (−0.07)	0.638*** (−0.07)	1.797*** (−0.15)	0.695*** (−0.08)	0.627 (−0.46)	0.782*** (−0.06)	1.624*** (−0.12)
Same Official Language	−0.07 (−0.14)	−0.172* (−0.07)	0.612*** (−0.05)	0.111 (−0.22)	0.414*** (−0.06)	−0.274 (−0.26)	0.555*** (−0.04)	−0.248* (−0.1)
Free Trade Agreement	−0.187 (−0.13)	−0.025 (−0.07)	0.137** (−0.04)	0.681*** (−0.13)	−0.136* (−0.06)	−0.677* (−0.33)	0.003 (−0.04)	−0.529*** (−0.11)
one partner is EU member	0.207 (−0.21)	0.364** (−0.14)	0.039 (−0.07)	0.075 (−0.29)	0.046 (−0.11)	2.211 (−3.23)	−0.023 (−0.06)	0.419* (−0.19)

both are EU member	−0.046 (−0.36)	1.064*** (−0.21)	0.391*** (−0.11)	0.998* (−0.41)	0.559** (−0.19)	4.63 (−6.34)	−0.009 (−0.1)	0.36 (−0.29)
N	22146	21299	41461	11279	30450	6421	51955	15124
Pseudo R^2	0.132	0.727	0.357	0.765	0.228	0.584	0.308	0.655

PPML[1] = PPML without zero-trade; Standard errors in parentheses; ***, ** and * are significant at the 0.1%, 1% and 5% level, respectively.

Table 3. Estimation results for the product group 'sawnwood'.

	Sawnwood		**Coniferous Sawnwood**		**Non-Coniferous Sawnwood**	
	ML	**PPML¹**	**ML**	**PPML¹**	**ML**	**PPML¹**
Constant	17.792	8.39**	1.752***	2.873	−1.202***	6.882*
	(−3263.15)	(−2.91)	(−0.5)	(−6.96)	(−0.31)	(−3.14)
Forest Rents (exporter)	−0.369**	0.194***	−0.039	0.397***	−0.019	0.097***
	(−0.11)	(−0.03)	(−0.02)	(−0.09)	(−0.01)	(−0.03)
Forest Rents (importer)	−0.071	−0.21*	−0.067**	−0.307	−0.126***	−0.109
	(−0.07)	(−0.1)	(−0.02)	(−0.17)	(−0.02)	(−0.08)
Production (exporter)	0.086*	0.074**	0.03**	0.301***	0.09***	0.509***
	(−0.04)	(−0.02)	(−0.01)	(−0.05)	(−0.01)	(−0.04)
Production (importer)	0.07*	−0.022**	0.000	−0.043**	0.045***	−0.029
	(−0.03)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.02)
Consumption (exporter)	−0.127*	−0.157***	−0.016	−0.097***	0.009	−0.072***
	(−0.05)	(−0.02)	(−0.01)	(−0.03)	(−0.01)	(−0.02)
Consumption (importer)	−0.215***	0.057**	0.086***	0.644***	0.072***	0.19***
	(−0.05)	(−0.02)	(−0.01)	(−0.04)	(−0.01)	(−0.04)
GDP per capita (exporter)	0.616**	0.028	0.042	0.289***	0.176***	−0.286***
	(−0.18)	(−0.04)	(−0.03)	(−0.05)	(−0.03)	(−0.06)
GDP per capita (importer)	0.253*	0.755***	0.14***	0.384***	0.297***	0.719***
	(−0.1)	(−0.04)	(−0.03)	(−0.06)	(−0.03)	(−0.05)
Distance between Capitals	−0.218	−0.974***	−1.135***	−1.032***	−1.006***	−1.106***
	(−0.12)	(−0.03)	(−0.02)	(−0.03)	(−0.02)	(−0.03)
Continuous Countries	−0.804*	1.082***	0.497***	1.311***	0.619***	0.648***
	(−0.33)	(−0.04)	(−0.06)	(−0.05)	(−0.06)	(−0.05)
Same Official Language	0.137	−0.025	0.509***	−0.17**	0.765***	0.075
	(−0.23)	(−0.04)	(−0.04)	(−0.05)	(−0.03)	(−0.05)
Free Trade Agreement	0.105	0.235***	0.094**	0.372***	0.081**	−0.213***
	(−0.2)	(−0.04)	(−0.03)	(−0.05)	(−0.03)	(−0.05)
one partner is EU member	1.024**	0.149*	0.235***	−0.11	−0.156***	0.875***
	(−0.38)	(−0.07)	(−0.05)	(−0.09)	(−0.04)	(−0.1)
both partners are EU member	2.162**	0.34**	0.681***	0.205	−0.433***	1.077***
	(−0.76)	(−0.13)	(−0.09)	(−0.16)	(−0.08)	(−0.16)
N	39922	39618	63192	22975	86531	33798
Pseudo R^2	0.066	0.827	0.371	0.887	0.377	0.685

PPML¹ = PPML without zero-trade; Standard errors in parentheses; ***, ** and * are significant at the 0.1%, 1% and 5% level, respectively.

Table 4. Estimation results for the product group 'veneer, plywood and fiberboard'.

	Veneer		**Plywood**		**Fiberboard**	
	ML	**PPML¹**	**ML**	**PPML¹**	**ML**	**PPML¹**
Constant	0.682	12.593***	−3.53***	4.945	−0.73	3.639
	(−0.48)	(−3.59)	(−0.56)	(−11.82)	(−0.6)	(−33.31)
Forest Rents (exporter)	0.053*	0.195***	0.089***	0.274***	0.1**	0.319*
	(−0.02)	(−0.03)	(−0.02)	(−0.02)	(−0.03)	(−0.14)
Forest Rents (importer)	−0.104***	−0.326***	−0.064***	−0.193**	−0.078***	−0.24
	(−0.02)	(−0.07)	(−0.01)	(−0.07)	(−0.02)	(−0.27)
Production (exporter)	0.057***	0.18***	0.093***	0.474***	0.06***	0.055
	(−0.01)	(−0.02)	(−0.01)	(−0.03)	(−0.01)	(−0.04)
Production (importer)	0.014*	−0.017	0.009	−0.025**	−0.017**	−0.023
	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.01)	(−0.02)
Consumption (exporter)	−0.023**	−0.027**	−0.006	0.123***	0.018*	0.013
	(−0.01)	(−0.01)	(−0.02)	(−0.03)	(−0.01)	(−0.04)
Consumption (importer)	0.06***	0.117***	0.141***	0.128***	0.055***	0.157*
	(−0.01)	(−0.02)	(−0.01)	(−0.03)	(−0.01)	(−0.07)

GDP per capita (exporter)	0.209***	0.413***	0.562***	0.227***	0.476***	0.869***
	(−0.03)	(−0.04)	(−0.03)	(−0.03)	(−0.03)	(−0.13)
GDP per capita (importer)	0.122***	−0.332***	0.217***	0.077	0.222***	0.028
	(−0.03)	(−0.03)	(−0.03)	(−0.05)	(−0.02)	(−0.06)
Distance between Capitals	−1.126***	−0.887***	−1.206***	−0.675***	−1.318***	−0.89***
	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.02)	(−0.07)
Continuous Countries	0.519***	0.394***	0.339***	0.611***	0.333***	0.888***
	(−0.06)	(−0.04)	(−0.06)	(−0.04)	(−0.06)	(−0.12)
Same Official Language	0.666***	0.772***	0.793***	0.422***	0.620***	0.138
	(−0.04)	(−0.04)	(−0.04)	(−0.05)	(−0.04)	(−0.14)
Free Trade Agreement	−0.038	0.102*	0.223***	1.091***	0.325***	0.369**
	(−0.03)	(−0.04)	(−0.03)	(−0.04)	(−0.03)	(−0.14)
one partner is EU member	0.104*	0.599***	0.028	−0.077	−0.253***	−0.622*
	(−0.05)	(−0.08)	(−0.05)	(−0.1)	(−0.05)	(−0.26)
both partners are EU member	0.457***	0.965***	0.314***	0.394*	0.031	−0.189
	(−0.09)	(−0.13)	(−0.09)	(−0.18)	(−0.09)	(−0.44)
N	57885	21959	71968	28052	66885	27821
Pseudo R^2	0.37	0.651	0.378	0.59	0.376	0.657

PPML[1] = PPML without zero-trade; Standard errors in parentheses; ***, ** and * are significant at the 0.1%, 1% and 5% level, respectively.

Table 5. Estimation results for the product group 'wood pulp, newsprint and paper and paperboard'.

	Wood Pulp		**Newsprint**		**Paper and Paperboard**	
	ML	**PPML[1]**	**ML**	**PPML[1]**	**ML**	**PPML[1]**
Constant	−1.113	−1.131	−10.296	8.683	−2.929***	0.471
	(−0.84)	(−46.33)	(−169.7)	(−11.15)	(−0.39)	(−4.06)
Forest Rents (exporter)	0.066	0.586***	−0.022	0.35	−0.102***	0.171***
	(−0.04)	(−0.11)	(−0.05)	(−0.25)	(−0.02)	(−0.05)
Forest Rents (importer)	−0.031	−0.004	−0.026	0.031	−0.038***	−0.017
	(−0.02)	(−0.11)	(−0.02)	(−0.11)	(−0.01)	(−0.02)
Production (exporter)	0.068***	0.125**	0.054***	0.443***	0.027***	0.229***
	(−0.01)	(−0.05)	(−0.01)	(−0.08)	(−0.01)	(−0.02)
Production (importer)	0.008	0.002	−0.014*	−0.027*	−0.016**	−0.028***
	(−0.01)	(−0.02)	(−0.01)	(−0.01)	(−0.01)	(−0.01)
Consumption (exporter)	0.025	0.008	0.000	−0.01	0.3***	0.389***
	(−0.02)	(−0.02)	(−0.01)	(−0.02)	(−0.03)	(−0.03)
Consumption (importer)	0.13***	0.407***	0.162***	0.373***	0.28***	0.435***
	(−0.01)	(−0.05)	(−0.01)	(−0.07)	(−0.02)	(−0.02)
GDP per capita (exporter)	0.113**	0.344***	0.35***	0.087	0.31***	0.411***
	(−0.04)	(−0.06)	(−0.04)	(−0.1)	(−0.03)	(−0.02)
GDP per capita (importer)	0.105***	0.499***	−0.017	0.124	0.073***	−0.074***
	(−0.03)	(−0.05)	(−0.02)	(−0.09)	(−0.02)	(−0.01)
Distance between Capitals	−0.966***	−0.718***	−1.231***	−0.761***	−1.305***	−0.87***
	(−0.03)	(−0.03)	(−0.03)	(−0.05)	(−0.02)	(−0.01)
Continuous Countries	0.716***	0.602***	0.484***	0.954***	0.438***	0.551***
	(−0.07)	(−0.05)	(−0.06)	(−0.09)	(−0.06)	(−0.01)
Same Official Language	0.455***	−0.246***	0.659***	0.305**	0.634***	0.152***
	(−0.05)	(−0.05)	(−0.05)	(−0.1)	(−0.03)	(−0.02)
Free Trade Agreement	0.027	0.203***	0.258***	0.654***	0.246***	0.657***
	(−0.04)	(−0.04)	(−0.04)	(−0.1)	(−0.03)	(−0.02)
one partner is EU member	0.129*	−0.502***	−0.273***	−0.364	−0.207***	−0.199***
	(−0.07)	(−0.11)	(−0.07)	(−0.24)	(−0.04)	(−0.04)
both partners are EU member	0.612***	−0.035	−0.109	0.045	0.381***	0.317***
	(−0.11)	(−0.21)	(−0.12)	(−0.44)	(−0.1)	(−0.06)
N	42253	16168	47377	16701	111673	57319
Pseudo R^2	0.401	0.87	0.355	0.9	0.465	0.869

PPML[1] = PPML without zero-trade; Standard errors in parentheses; ***, ** and * are significant at the 0.1%, 1% and 5% level, respectively.

References

1. Kastner, T.; Erb, K.-H.; Nonhebel, S. International wood trade and forest change: A global analysis. *Glob. Environ. Chang.* **2011**, *21*, 947–956, doi:10.1016/j.gloenvcha.2011.05.003.
2. Guan, Z.; Xu, Y. The policy analysis of governing illegal logging: A game theory approach. *J. Sustain. For.* **2018**, *37*, 727–738, doi:10.1080/10549811.2018.1478308.
3. Lovrić, M.; Da Re, R.; Vidale, E.; Pettenella, D.; Mavsar, R. Social network analysis as a tool for the analysis of international trade of wood and non-wood forest products. *For. Policy Econ.* **2018**, *86*, 45–66, doi:10.1016/j.forpol.2017.10.006.
4. Buongiorno, J. Monetary union and forest products trade—The case of the euro. *J. For. Econ.* **2015**, *21*, 238–249, doi:10.1016/j.jfe.2015.09.005.
5. Johnston, C.M.T.; van Kooten, G.C. Global trade impacts of increasing europe's bioenergy demand. *J. For. Econ.* **2016**, *23*, 27–44, doi:10.1016/j.jfe.2015.11.001.
6. Morland, C.; Schier, F.; Janzen, N.; Weimar, H. Supply and demand functions for global wood markets: Specification and plausibility testing of econometric models within the global forest sector. *For. Policy Econ.* **2018**, *92*, 92–105, doi:10.1016/j.forpol.2018.04.003.
7. Tinbergen, J. Shaping the World Economy; Suggestions for an International Economic Policy; Twentieth Century Fund: New York, NY, USA, 1962.
8. De Benedictis, L.; Taglioni, D. The gravity model in international trade. In *The Trade Impact of European Union Preferential Policies: An Analysis Through Gravity Models*; De Benedictis, L., Salvatici, L., Eds.; Springer: Berlin/Heidelberg, Germany, 2011; pp 55–89, doi:10.1007/978-3-642-16564-1_4.
9. Zahniser, S.S.; Pick, D.; Pompelli, G.; Gehlhar, M.J. Regionalism in the western hemisphere and its impact on u.S. Agricultural exports: A gravity-model analysis. *Am. J. Agr. Econ.* **2002**, *84*, 791–797, doi:10.1111/1467-8276.00338.
10. Akyüz, K.C.; Yildirim, I.; Balaban, Y.; Gedik, T.; Korkut, S. Examination of forest products trade between turkey and european union countries with gravity model approach. African journal of biotechnology. *Afr. J. Biotechnol.* **2010**, *9*, 2375–2380.
11. Huang, L.; Chen, K.; Zhou, M.; Nuse, B. Gravity models of china's bamboo and rattan products exports: Applications to trade potential analysis. *For. Prod. J.* **2019**, *69*, 337–344, doi:10.13073/fpj-d-19-00022.
12. Buongiorno, J. Gravity models of forest products trade: Applications to forecasting and policy analysis. *Forestry* **2016**, *89*, 117–126, doi:10.1093/forestry/cpw005.
13. Larson, J.; Baker, J.; Latta, G.; Ohrel, S.; Wade, C. Modeling international trade of forest products: Application of ppml to a gravity model of trade. *For. Prod. J.* **2018**, *68*, 303–316, doi:10.13073/fpj-d-17-00057.
14. Pfaffermayr, M. Gravity models, ppml estimation and the bias of the robust standard errors. *Appl. Econ. Lett.* **2019**, *26*, 1467–1471, doi:10.1080/13504851.2019.1581902.
15. Anderson, J.E. A theoretical foundation for the gravity equation. *Am. Econ. Rev.* **1979**, *69*, 106–116.
16. Anderson, J.E.; Yotov, Y.V. The changing incidence of geography. *Am. Econ. Rev.* **2010**, *100*, 2157–2186, doi:10.1257/aer.100.5.2157.
17. Anderson, J.; Yotov, Y. *Gold Standard Gravity*; Nber Working Paper No. 17835; National Bureau of Economic Research: Cambridge, MA, USA, 2012, doi:10.3386/w17835.
18. Head, K.; Mayer, T. *Gravity Equations: Workhorse, Toolkit, and Cookbook*: Elsvier: Kidlington, UK, 2014; Volume 4, pp. 131–195, doi:10.1016/b978-0-444-54314-1.00003-3.
19. Anderson, J.E. The gravity model. *Annu. Rev. Econ.* **2011**, *3*, 133–160, doi:10.1146/annurev-economics-111809-125114.
20. Cameron, A.C.; Gelbach, J.B.; Miller, D.L. Robust inference with multiway clustering. *J. Bus. Econ. Stat.* **2011**, *29*, 238–249, doi:10.1198/jbes.2010.07136.
21. Silva, J.M.C.S.; Tenreyro, S. The log of gravity. *Rev. Econ. Stat.* **2006**, *88*, 641–658, doi:10.1162/rest.88.4.641.
22. Paternoster, R.; Brame, R.; Mazerolle, P.; Piquero, A. Using the correct statistical test for the equality of regression coefficients. *Criminology* **1998**, *36*, 859–866, doi:10.1111/j.1745-9125.1998.tb01268.x.
23. CEPII. Geodist database. Available online: http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=6 (accesed on 16 August 2019).

24. Mayer, T.; Zignago, S. *Notes on cepii's distances measures: The geodist database*. CEPII Working Paper 2011–25; CEPII: Paris, France, 2011. Available online: http://www.cepii.fr/CEPII/en/publications/wp/abstract.asp?NoDoc=3877.
25. FAO. Forest produtction and trade, 2019,. Available online: http://www.fao.org/faostat/en/#data/FO (accesed on 16 August 2019).
26. FAO. Forestry trade flows, 2019. Available online: http://www.fao.org/faostat/en/#data/FT (accesed on 16 August 2019).
27. WorldBank. World development indicators, 2019. Available online: http://datatopics.WorldBank.org/world- development-indicators/ (accesed on 16 August 2019).
28. UnitedNations. Un comtrade, 2019. Available online: http://comtrade.un.org/. (accesed on 12 September 2019).