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Impacts of the FLEGT Action Plan and the EU Timber Regulation on EU Trade in Timber Product

Paul Rougieux * and Ragnar Jonsson

European Commission, Joint Research Center (JRC), Directorate D—Sustainable Resources, Bio-Economy, Via E. Fermi 2749, I-21027 Ispra, Italy; ragnar.jonsson@ec.europa.eu

* Correspondence: paul.rougieux@ec.europa.eu

Abstract: The EU Timber Regulation (EUTR) is a key element in the efforts of the European Union to curb the trade in illegal timber products. This study helps to remedy the lack of systematic, statistical analysis of the EUTR's potential impacts on international trade in timber products. Using cointegration intervention—or shock—models we quantify potential shifts in import prices and quantities of tropical hardwood lumber and oak lumber after the entry into effect of the EUTR. We further estimate import demand models to assess the relation between temperate and tropical hardwood products and whether there was a structural change in demand elasticities after the entry into force of the EUTR. The shock model analysis indicates, for most of the bilateral trade flows where we observe cointegration and a significant shock variable, increasing import prices and decreasing import quantities of tropical hardwood lumber following the EUTR start date, consistent with a contraction of the supply of tropical timber. The results of the import demand models do not give a clear indication as to whether oak lumber is a complementary or substitute product for tropical hardwood lumber, and there are no clear signs of structural changes in demand elasticities. Aside from the analysis, an important contribution of the paper is the procedure for building a long and homogeneous time series of tropical hardwood lumber.

Keywords: illegal logging; trade; FLEGT; EUTR; time series econometrics; econometrics of panel data

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Citation: Rougieux, P.; Jonsson, R. Impacts of the FLEGT Action Plan and the EU Timber Regulation on EU Trade in Timber Product. *Sustainability* **2021**, *13*, 6030. https://doi.org/10.3390/su13116030

Academic Editor: Pierfrancesco De Paola

Received: 30 April 2021
Accepted: 24 May 2021
Published: 27 May 2021

1. Introduction

Illegal logging and the associated trade in timber products undermine legal timber trade and have detrimental environmental, economic, and social impacts [1]. The European Commission presented the Forest Law Enforcement, Governance, and Trade (FLEGT) Action Plan [2] as part of its endeavors to tackle illegal logging. Acknowledging the shared responsibility of exporters and importers, the objective is to eliminate illegal timber in international trade. A cornerstone of the FLEGT action plan is establishing Voluntary Partnership Agreements (VPAs) with timber producing and exporting countries, and the introduction of FLEGT-licensed timber [1]. A second key element of the plan is the EU Timber Regulation [3], which came into force on 3 March 2013. VPAs and the EUTR are meant to reinforce each other, addressing the supply (export) and demand (import) side of the timber product trade respectively (Figure 1).

A pertinent question then is what influences FLEGT and the EUTR, as well as other similar initiatives such as the US Lacey Act Amendment (LAA), have had on international trade in timber products. Estimates of the scale of illegal timber trade are surrounded by considerable uncertainty, since illegal trade is not recorded in trade databases [4]. Lawson and McFaul [5]—in assessing the effects of the LAA, FLEGT, and other efforts to reduce illegal logging through a combination of (i) surveys involving government officials, NGOs, and firms with (ii) the evaluation of trade and production data—found that illegal logging and exports of illegally sourced timber had decreased while timber product prices had risen since the beginning of the 2000s. Prestemon [6] performed econometric analysis on

U.S. import data to assess the impact of the LAA. The results indicate general increases in prices and decreases in quantities of tropical hardwood imports to the U.S. from countries suspected of a high degree of illegal timber trade.

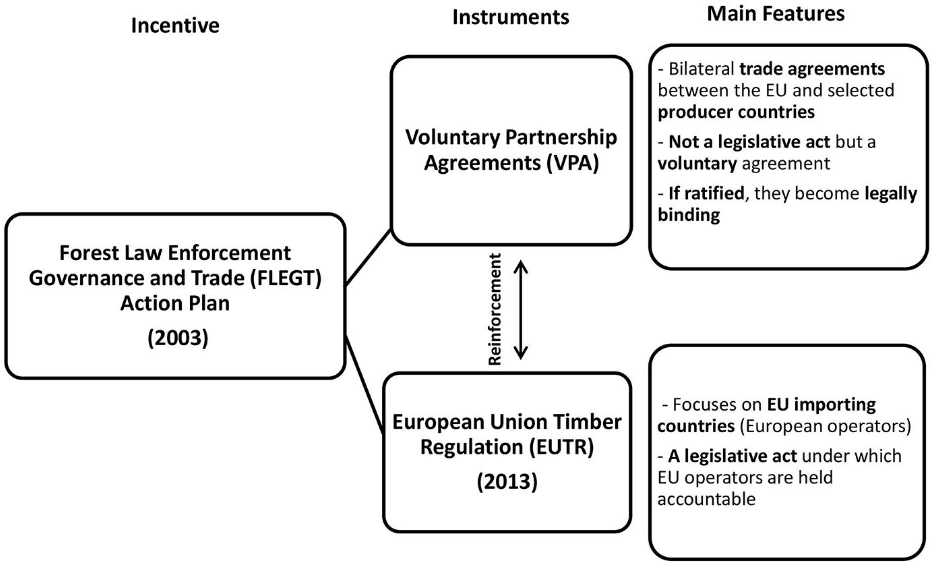

Figure 1. The FLEGT Action Plan with its two main instruments and their main features. Source: [7].

Due to the rather short time the EUTR has been in force, there are yet no studies that have performed systematic, comprehensive statistical analysis regarding the impacts on international trade in timber products. Anecdotal evidence suggests that the main reason for declining tropical timber demand in the EU is substitution by temperate timber [8,9]. The European flooring industry in particular has reported a significant fall in the use of tropical timbers, to a large extent attributed to environmental concerns [10]—illegal timber trade is primarily associated with tropical hardwood [11]. It is claimed that EUTR may have been key in reinforcing this trend, through increased costs of conforming to the requirements of the EUTR [7–9].

Figure 2 gives some support to this claim, illustrating shrinking imports of tropical hardwoods from extra EU countries while temperate hardwood imports are rather stable through time. In addition, Figure 2 reports on intra EU trade to highlight three facts and a limitation of the Comext database. First, the intra EU trade of other sawnwood is an order of magnitude higher than that of oak and tropical hardwood lumber (note the differences in scales). Second, the intra EU trade of oak lumber has been increasing dramatically in recent years. Third there is a stable intra EU trade of tropical hardwood lumber throughout the period, and the limitation of our data source is that there is only data on the European partner country for such trade flows, but not the original tropical country of production. The extra-EU imports that are then re-exported within the EU are not accounted for in our analysis. This is why aggregating the EU as a whole leads to loss of information. It is not an issue for the demand model since in that case we are not investigating the source of tropical timber but the overall consumption of tropical timber.

The objective of this study is to assess trade effects of FLEGT and the EUTR: Have the patterns of EU imports of hardwood timber products changed as a result of FLEGT and the EUTR? We address this overriding question by analyzing the effects of FLEGT and the EUTR on imported quantities and prices of selected hardwood products. To accomplish this, we use two classes of statistical models. Hence, we use cointegration intervention models to quantify potential shifts—corresponding with the implementation of the EUTR—in the cointegrating relations of import prices and quantities of tropical hardwood lumber and oak lumber respectively. In addition, we estimate an import demand model to assess the relation between temperate and tropical hardwood products, trying to establish whether they are substitutes or complements and analyzing whether there was a structural change in demand elasticities after the entry into force of the EUTR.

Figure 2. EU sawnwood imports from extra and intra EU partners. The Combined Nomenclature code 44072969 represents tropical hardwood lumber products analyzed in this article. EU = EU27 + UK.

We hypothesize that the implementation of the EUTR resulted in a reduction of supply of tropical timber to EU member states, a result of the discontinuation of the supply of illegal timber and/or the disappearance of some of the legal supply due to the costs of conforming to the requirements of the EUTR. This backward shift of the supply curve would result in a new equilibrium market solution at the higher price, P2, and lower quantity, Q2, in the tropical timber market, ceteris paribus (Figure 3). However, substitution by temperate timbers, such as oak, for tropical timber would in addition to increasing the equilibrium price and quantity in the temperate timber market through increased demand (Figure 3), result in a contraction of the demand (a backwards shift of the demand curve) for the tropical timber being substituted. While this would reinforce the decrease in the equilibrium quantity, it would counter the increase in the equilibrium price in the tropical timber market. The sign of the price movement will depend on the relative strength of the supply and demand shock respectively. The next section describes in detail the data and methods used in the analysis. Then results are reported, followed by the discussion and conclusions.

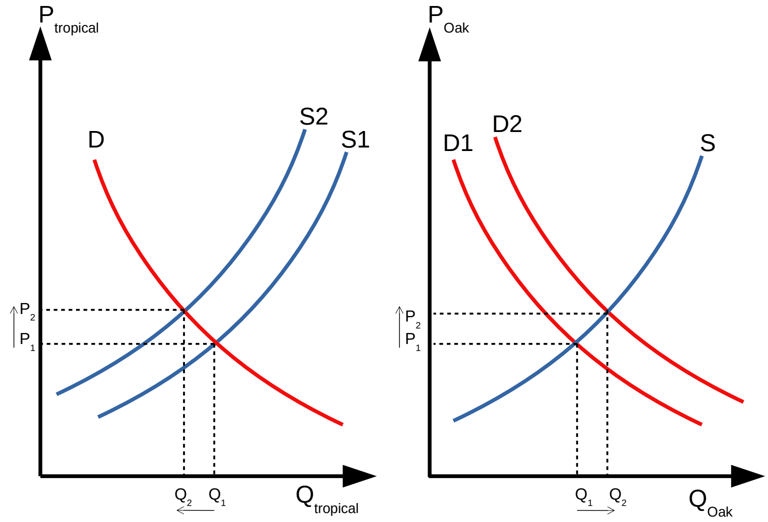

Figure 3. Supply and demand curve for the markets of tropical timber and oak timber.

2. Materials and Methods

2.1. Shock Model

In an attempt to isolate the effect of the policy change from other economic variations, we analyze the price series of substitute or complementary products. Such products should be affected by economic variations in a similar way throughout the period, thus we look for a difference in how they relate to each other before and after the entry into force of the EUTR. Rather than estimating the effect of the shock directly with a dummy variable in a linear model, we follow the more robust approach of a cointegration intervention model [6]. The analysis starts by splitting the price series before and after the entry into force of the EUTR. We first estimate the relationship between the price of tropical products P_{rt} and the price of temperate products P_{mt} before the shock date (Equation (1)):

$$\ln P_{rt} = \gamma_0 + \gamma_1 \ln P_{mt} + \theta_t. \tag{1}$$

The estimated coefficients are then used to generate pseudo errors $\hat{\mu}_t$ after the shock date (Equation (2)). These pseudo errors contain information on how the relationship between the two products change after the shock. Third, the $\hat{\mu}_t$ vector is regressed onto a lagged version of itself to estimate λ, the size of the shock in Equation (3):

$$\hat{\mu}_t = \ln P_{rt} - \hat{\gamma}_0 - \hat{\gamma}_1 \ln P_{mt} \tag{2}$$

$$\hat{\mu}_t = \omega_0 + \omega_1 \hat{\mu}_{t-1} + \lambda S_t + \epsilon_t. \tag{3}$$

The λ coefficient gives an indication as to how the shock impacted the relationship between tropical and temperate prices. Since we estimate the model with the log of prices, $e^{\lambda} - 1$ can be interpreted as a percentage change of prices between a model without the shock and a model with the shock. The same shock model is used to estimate the relationship between the import weight series.

2.2. Demand Model

The theoretical background behind the import demand for forest products is explained in [12], based on the general formulation by [13]. The simplest formulation of a macroeconomic demand model relates Y_{rt}, the import demand of tropical timber within one country at time t to the price of tropical timber P_{rt} (proxied by the unit price of trade) and national revenue proxied by G_t, the GDP at time t. It is estimated in its logarithm form (Equation (4)). This static model is sometimes estimated in a dynamic form by adding a lagged version of the demand $Y_{r(t-1)}$ as an additional regressor, but we only estimate the static version here:

$$\ln Y_{rt} = \beta_0 + \beta_1 \ln P_{rt} + \beta_3 \ln G_t. \quad (4)$$

Some authors use simultaneous equations to estimate demand and supply in one model [14,15], but such estimations require additional exogenous variables as determinants of the supply side and are therefore generally done on a national level. International demand models on the other hand [12,16,17] are generally estimated with a single equation, independently of the supply. Thus making the assumption that the supply is infinitely elastic. This is a limitation of our model which we could not address at this stage.

To the simple demand model (Equation (4)), we add an additional explanatory variable representing the price of a substitute or complementary product (Equation (5)). The β_2 coefficient can be interpreted as a cross price elasticity of demand:

$$\ln Y_{rt} = \beta_0 + \beta_1 \ln P_{rt} + \beta_2 \ln P_{mt} + \beta_3 \ln G_t. \quad (5)$$

We estimate the demand model (Equation (5)) from a balanced panel dataset. To capture the unobserved heterogeneity between countries, the estimation is performed with individual country fixed effects. Before performing the estimation, we test for the presence of autocorrelation issues with panel stationarity tests. In the case of a non stationary series, we also estimate the model with differenced variables to remove potential issues with autocorrelation. The problem with results based on differenced variables is that the coefficients cannot be interpreted as elasticities, still, the sign and strength of the coefficient give indications for model comparisons.

3. Data Preparation

It is preferable to use a narrow product group so that changing prices represent a market signal and not a change of the product mix among a large basket of products. CN codes of temperate sawnwood such as oak have remained the same throughout the whole period. Unfortunately, there has been several changes in tropical hardwood lumber product codes throughout the last 20 years and it is not possible to find a stable tropical timber product code at the CN8 level because product descriptions change through time. For example in 2007 product code 444072969 was split into three different codes (44072799, 44072899, and 44072968) described Table A1 in Appendix A. While in 2017, product code 44072960 was merged into 44072995. These changes are visible Figure A2 in the subplot showing the EU's imports from Africa. To build a long time series of tropical hardwood lumber, we selected products related to 44072969, which is the sawnwood product with the highest import value over the period. A correspondance table from EUROSTAT describes changes in the Combined Nomenclature of the EU's external trade statistics [18]. Based on that table, we built a procedure that looks forward in time for all products related to 44072969 and then backward for all products that have been related to these products in the past. From that list we excluded the products codes that are not specific to tropical timber. In particular we excluded product codes starting with 440799. These products are visible in a separate pane as shown in Figure A2. We exclude these product codes because they are not specific to tropical timber and represent mixes of timber of other origins. The procedure leads to an aggregated product category that represents the vast majority of tropical hardwood lumber export in most countries (Figure A1). However there are exceptions such as Malaysia and Indonesia where the chosen product aggregation represents only a fourth of the trade value exported to the EU.

The shock model relates the bilateral import price (and weight) series of tropical timber to the import price (and weight) series of oak. The trade partner chosen for oak lumber imports is the USA, for most EU member states the most important extra-EU supplier. A monthly time series was used to increase the power of the estimation. The estimation techniques require a full time series, but many country pairs do not have a complete series. The detail number of missing data for all country pairs are visible in

Table A2. Countries with low trade volumes (Table A3) are more likely to have missing data points. We selected country pairs which have zero missing values, in addition we performed linear interpolation for country pairs which had few missing values (less than 20 missing values out of 228 observations). We omitted the other country pairs because they did not have enough observations.

Figure A3 illustrates the evolution of monthly prices, trade values, and weight for some of the largest EU tropical hardwood lumber importers from Cameroon. In Germany and Italy, the import weight and prices of tropical hardwood lumber have the same order of magnitude as the import weight and prices of oak lumber, for this reason the comparison makes most sense in those country pairs. France on the other hand imports very low volumes of oak from the USA, mainly because it is itself a large oak producer. Spain's imports of tropical and oak lumber have strongly decreased after the 2008 financial crisis and never recovered since then. The tropical hardwood lumber import series for Malaysia however show much lower import values compared to oak lumber imports in Germany, Italy, and the UK (Figure A4). Note also the presence of outliers in the Netherlands, as well as the drastic decrease of lumber exports to Belgium. The variable `pricew` visible in those figures is the ratio of the trade value and weight. This trade unit value is used as a price proxy in the econometric models. It is also possible to compute a price based on the import quantity in cubic metres, but the quantity has more missing data or outliers. That is why we prefer to use the price per units of weight.

The demand model relates aggregate import demand to three variables: The import price of tropical timber, the import price of temperate timber, and GDP. GDP is expressed in constant prices of 2015 based on the chain linked volume method [19]. Monthly GDP data are not available, so we use yearly data. In addition, yearly data smooths seasonal variations which could affect the topical and temperate markets in different ways but the use of yearly data reduces the number of observations from 228 to 19 which negatively impacts the power of the estimation. A further restriction is imposed by the fact that the estimation methods require a balanced panel i.e., observations should be present in all years for all variables and all countries. We removed Cyprus and Malta as they have only 16 years of data and they have the lowest tropical timber import trade value of all countries. We started the series in 2002 to obtain a balanced panel with the largest cross section (N) dimension and the longest time dimension (T) possible. Descriptive statistics of the panel variables used in the demand model are visible in Table A6. Imported weights of tropical hardwood lumber are higher than those of oak in Belgium and France, while they are of a similar order of magnituted in large importing countries such as Germany and Italy (Figure A6), most of the remaining countries import higher oak quantities than tropical hardwood. All import prices follow increasing trends (Figure A7) with tropical prices generally higher than oak prices.

4. Results and Discussion

4.1. Shock Model Estimated on Time Series

Augmented Dickey Fuller (ADF) tests were performed on the period before the shock data to avoid the potential influence of the shock on the stationarity result. Tables A4 and A5 show that price series are non stationary (I(1)) for most country pairs. Therefore the use of cointegration methods is relevant to avoid spurious regression.

In the fifth column of Table 1 (and Table 2), the cointegration statistics are below the critical value of -3.37 for 28 country pairs (37 country pairs). For those country pairs we reject the null hypothesis that the residuals have unit roots, i.e., the price (weight) series of tropical and oak lumber are cointegrated. Results for the country pair, the Netherlands and Malaysia are not reliable because of the presence of outliers (see Figure A4).

Table 1. Estimation of a cointegration intervention model between the price series of tropical hardwood lumber and oak lumber. The oak import partner is the U.S. for all countries. Prices are transformed to natural logarithms.

Reporter	Partner T	VPA	Ndiffs	Coint Stat	Coint	$e^{\lambda} - 1$	p-Value	R^2	$\frac{weight_T}{weight_K}$
Belgium	Cameroon	vpa	1	−3.20		0.03	0.04	0.27	18.40
	Brazil		1	−2.81		0.05	0.04	0.54	2.06
Denmark	Brazil		1	−2.35		0.15	0.00	0.70	0.93
France	Brazil		1	−2.39		−0.02	0.37	0.51	6.27
	Cameroon	vpa	1	−3.11		0.01	0.31	0.34	9.60
Italy	Gabon		1	−2.87		0.09	0.00	0.71	0.78
	Côte d'Ivoire		1	−2.96		0.09	0.00	0.65	0.46
Netherlands	Cameroon	vpa	1	−3.06		0.12	0.00	0.61	2.83
	Brazil		1	−2.05		0.34	0.00	0.11	1.76
Portugal	Brazil		1	−2.27		0.09	0.00	0.66	0.56
Spain	Cameroon	vpa	1	−3.10		0.04	0.00	0.44	1.08
	Côte d'Ivoire		1	−2.73		0.21	0.00	0.42	0.14
Utd. Kingdom	Cameroon	vpa	1	−3.20		0.15	0.00	0.75	0.51
Belgium	Côte d'Ivoire		0	−5.52	coint	−0.18	0.00	0.27	2.14
	Ghana	vpa	1	−7.50	coint	0.01	0.81	0.03	0.32
	Gabon		1	−7.75	coint	0.08	0.00	0.07	6.80
	Malaysia		1	−3.58	coint	0.13	0.00	0.19	0.29
	Congo DRC		1	−5.36	coint	0.15	0.00	0.43	1.89
France	Malaysia		1	−4.80	coint	0.01	0.74	0.25	1.73
	Côte d'Ivoire		1	−3.65	coint	0.03	0.34	0.13	0.79
	Ghana	vpa	1	−3.49	coint	0.04	0.14	0.02	0.97
	Gabon		1	−6.18	coint	0.05	0.01	0.08	1.31
	Congo	vpa	1	−5.01	coint	0.06	0.00	0.16	2.67
Germany	Ghana	vpa	1	−5.18	coint	0.12	0.00	0.77	0.34
	Cameroon	vpa	1	−5.07	coint	0.27	0.00	0.59	0.34
	Malaysia		1	−4.40	coint	0.83	0.00	0.25	0.06
Greece	Côte d'Ivoire		1	−5.84	coint	0.08	0.00	0.11	0.74
	Cameroon	vpa	1	−6.44	coint	0.10	0.00	0.10	0.65
Ireland	Cameroon	vpa	1	−7.87	coint	0.22	0.00	0.23	2.72
Italy	Congo	vpa	0	−5.44	coint	0.12	0.00	0.14	0.12
	Cameroon	vpa	1	−4.77	coint	0.13	0.00	0.69	1.24
	Ghana	vpa	1	−4.95	coint	0.16	0.00	0.32	0.06
	Malaysia		1	−4.55	coint	0.24	0.00	0.08	0.10
Netherlands	Malaysia		1	−4.79	coint	−0.30	0.00	0.43	5.02
	Côte d'Ivoire		1	−6.17	coint	0.07	0.20	0.02	0.77
Portugal	Cameroon	vpa	1	−3.66	coint	0.04	0.03	0.33	0.46
	Gabon		1	−7.23	coint	0.10	0.00	0.11	0.22
Spain	Brazil		1	−3.74	coint	−0.02	0.53	0.30	0.26
Utd. Kingdom	Malaysia		1	−3.80	coint	0.12	0.00	0.39	0.11
	Côte d'Ivoire		1	−4.34	coint	0.15	0.00	0.66	0.13
	Ghana	vpa	1	−6.08	coint	0.16	0.00	0.16	0.05

Table 2. Estimation of a cointegration intervention model between the import weight series of tropical hardwood lumber and oak lumber. Variables are transformed to natural logarithms.

Reporter	Partner T	VPA	Ndiffs	Coint Stat	Coint	$e^{\lambda} - 1$	p-Value	R^2	$\frac{weight_T}{weight_K}$
France	Brazil		1	−3.24		−0.24	0.00	0.61	6.27
Italy	Ghana	vpa	1	−2.18		−0.42	0.00	0.57	0.06
	Côte d'Ivoire		1	−1.74		−0.17	0.01	0.77	0.46
	Cameroon	vpa	1	−2.33		−0.08	0.13	0.53	1.24
Belgium	Ghana	vpa	0	−5.12	coint	−0.22	0.01	0.07	0.32
	Congo DRC		1	−5.75	coint	−0.12	0.29	0.13	1.89
	Malaysia		1	−5.54	coint	0.06	0.64	0.07	0.29
	Brazil		0	−5.51	coint	0.17	0.03	0.21	2.06
	Cameroon	vpa	1	−4.33	coint	0.23	0.00	0.35	18.40
	Côte d'Ivoire		0	−5.53	coint	0.80	0.00	0.23	2.14
	Gabon		1	−5.91	coint	1.00	0.00	0.22	6.80
Denmark	Brazil		0	−7.22	coint	0.15	0.18	0.07	0.93
France	Côte d'Ivoire		1	−5.52	coint	−0.60	0.00	0.29	0.79
	Ghana	vpa	1	−3.95	coint	−0.59	0.00	0.25	0.97
	Malaysia		0	−7.72	coint	−0.40	0.00	0.17	1.73
	Cameroon	vpa	0	−6.11	coint	−0.16	0.00	0.06	9.60
	Gabon		1	−5.64	coint	−0.12	0.16	0.02	1.31
	Congo	vpa	0	−5.64	coint	0.33	0.00	0.09	2.67
Germany	Malaysia		1	−4.96	coint	−0.68	0.00	0.29	0.06
	Cameroon	vpa	1	−7.31	coint	−0.54	0.00	0.31	0.34
	Ghana	vpa	1	−4.42	coint	−0.38	0.00	0.57	0.34
Greece	Côte d'Ivoire		1	−7.50	coint	0.14	0.17	0.01	0.74
	Cameroon	vpa	0	−7.28	coint	0.71	0.00	0.09	0.65
Ireland	Cameroon	vpa	1	−5.32	coint	0.00	0.99	0.09	2.72
Italy	Malaysia		1	−3.78	coint	−0.57	0.00	0.40	0.10
	Congo	vpa	0	−7.62	coint	−0.20	0.07	0.08	0.12
	Gabon		1	−4.20	coint	−0.01	0.93	0.18	0.78
Netherlands	Côte d'Ivoire		0	−4.63	coint	−0.54	0.00	0.23	0.77
	Cameroon	vpa	1	−4.85	coint	0.14	0.20	0.12	2.83
	Brazil		1	−4.45	coint	0.41	0.07	0.12	1.76
	Malaysia		1	−5.45	coint	0.60	0.00	0.37	5.02
Portugal	Brazil		1	−5.13	coint	−0.36	0.00	0.28	0.56
	Cameroon	vpa	0	−8.06	coint	−0.35	0.00	0.13	0.46
	Gabon		0	−7.20	coint	0.46	0.00	0.07	0.22
Spain	Côte d'Ivoire		1	−4.82	coint	−0.34	0.00	0.33	0.14
	Brazil		1	−5.79	coint	0.00	0.99	0.03	0.26
	Cameroon	vpa	1	−6.67	coint	0.12	0.06	0.06	1.08
Utd. Kingdom	Ghana	vpa	1	−4.81	coint	−0.50	0.00	0.32	0.05
	Malaysia		1	−4.18	coint	−0.42	0.00	0.34	0.11
	Côte d'Ivoire		0	−5.77	coint	−0.39	0.00	0.40	0.13
	Cameroon	vpa	0	−8.05	coint	−0.08	0.20	0.01	0.51

For the country pairs Belgium—Ghana, France—Malaysia, France—Côte d'Ivoire, France—Ghana, Netherlands—Côte d'Ivoire, and Spain—Brazil, λ is not significantly different from zero, meaning that there is no significant change in the price relationship after the EUTR start date. In 22 of the cointegrated price series, the lambda coefficients are significant, and of these all but two, Belgium—Côte d'Ivoire and Netherlands—Malaysia, are positive (Table 1). This implies, with these two exceptions, increasing prices for tropical hardwood lumber following the introduction of the EUTR, ranging from 4% (Portugal—Cameroon) to 83% (Germany—Malaysia).

The results of a shock model based on a time series of import weights (Table 2)—show more cases where λ is not significantly different from zero (for the country pairs Belgium—Congo DRC, Belgium—Malaysia, Denmark—Brazil, France—Gabon, Greec e—Côte d'Ivoire, Ireland—Cameroon, Italy—Congo, Italy—Gabon, Netherlands—Brazil, Netherlands—Cameroon, Spain—Brazil, Spain—Cameroon, and Utd. Kingdom—Cameroon). Eight country pairs—of which four Belgian import partners, all important in terms of trade volumes—have significant and positive lambdas, indicating increasing imports of tropical hardwood lumber relative to temperate lumber imports after the shock. The remaining 16 country pairs have significant and negative lambdas, implying decreasing imports of tropical lumber relative to oak lumber imports after the introduction of the EUTR. In percentage terms, German imports of tropical hardwood lumber from Malaysia and French imports from Côte d'Ivoire show notable reductions. In quantity terms, however, there are many other tropical hardwood lumber import flows that show stronger reductions after the shock, such as, e.g., German imports from Cameroon, French imports from Cameroon and Ghana, and Portuguese imports from Brazil and Cameroon. Figure A5 illustrates how a negative lambda captures some of the decrease in residuals after the EUTR start date, leading to a change of model from the dotted blue curve to the red curve (particularly visible in the quadrants of Germany for example). VPA member countries (third column in Tables 1 and 2) do not exhibit any clear pattern that would distinguish them from non-VPA countries.

Hence, our results from the shock model show considerable consistency with those of Prestemon [6], as there are general increases in the prices and decreases in the import quantities of tropical timber relative to temperate timber after the implementation of a policy instrument aimed at curbing the trade in illegal timber. This pattern is consistent with a reduction of the supply of tropical timber to these EU member states. There are however notable exceptions of coincedental decreasing prices and increases in import quantities of tropical sawnwod, which would be consistent with an increase in the supply of tropical timber in these cases.

4.2. Demand Model Estimated on Panel Data

Before performing the estimation of the demand models, we tested the stationarity of the individual time series and of the panel as a whole. Augmented Dickey–Fuller tests fail to reject the null hypothesis of stationarity for most time series in most countries (Table A7). Panel stationarity tests reported in Table A8 are less conclusive. The Maddala and Wu and Levin–Lin–Chu tests both assume a null hypothesis that some of the series in the panel have a unit root. Both tests reject the null hypothesis for the explained variable, i.e., import demand can be considered stationary. The Maddala and Wu test rejects the null hypothesis for both price variables but the Levin–Lin–Chu weakly fails to reject the null. The Hadri test rejects the null hypothesis of stationarity for all variables. It should be noted that stationarity tests can be biased in the presence of structural breaks. In the absence of a clear answer in favor of stationarity, we have estimated the model with variables in level and with differenced variables. Estimated coefficients (Table 3) are reported with clustered standard errors to adjust for the fact that in a panel fixed effect model, the composite error term is correlated over time [20].

Table 3 shows, first of all, that the own price elasticity of import demand is negative, as expected by the theory. It is however only significant, and elastic, which is considerably higher than the elasticity of -0.7 estimated by Turner and Buongiorno [12], over the whole period and the first time period, becoming insignificant for the period following the EUTR implementation. Second, the cross-price elasticity with respect to oak lumber is never significant, and the same applies to the income elasticity of demand. In general, the demand models fit poorly with the explanatory variables, a consequence of the important inter-country variability.

Table 3. Panel data fixed effects estimation of a tropical hardwood lumber demand model.

	Dependent Variable:					
		Lweight_Trop			**Diff(Lweight_Trop)**	
	2002–2019	**2002–2013**	**2014–2019**	**2003–2019**	**2003–2013**	**2015–2019**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
lpricew_trop	−1.239 ***	−1.373 ***	−0.278			
	(0.313)	(0.392)	(0.226)			
lpricew_oak	0.041	0.328	−0.081			
	(0.187)	(0.213)	(0.191)			
lgdp_const_eur	0.029	0.820	−0.162			
	(0.494)	(0.532)	(0.990)			
diff(lpricew_trop)				−0.830 ***	−1.004 ***	−0.695 ***
				(0.107)	(0.140)	(0.143)
diff(lpricew_oak)				−0.091	0.004	−0.219
				(0.086)	(0.171)	(0.201)
diff(lgdp_const_eur)				5.240 ***	5.785 ***	−0.300
				(0.739)	(0.759)	(1.404)
Observations	432	288	144	408	264	120
R^2	0.270	0.233	0.021	0.287	0.383	0.130

Note: *** $p < 0.01$.

We also estimated an oak import demand model (Table 4). The own price elasticity is negative, again in accordance with theory, and stable through time. A price elasticity equal to −0.7 is similar to the value obtained in the fixed effect estimation of a static import demand model by Turner and Buongiorno [12]. Clearly the own price elasticity of oak import demand does not change over time. Furthermore, the cross-price elasticity with respect to tropical hardwood lumber is not significant over the whole time period and before the EUTR start date. It is significant and positive when estimated over the 2014–2019 period, indicating that tropical and oak lumber are substitutes, but it is not significant when estimated on differenced variables.

Table 4. Panel data fixed effects estimation of oak lumber demand.

	Dependent Variable:					
		Lweight_Oak			**Diff(Lweight_Oak)**	
	2002–2019	**2002–2013**	**2014–2019**	**2003–2019**	**2003–2013**	**2015–2019**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
lpricew_trop	−0.186	−0.323	0.304 **			
	(0.248)	(0.251)	(0.150)			
lpricew_oak	−0.727 ***	−0.753 ***	−0.713 ***			
	(0.102)	(0.221)	(0.105)			
lgdp_const_eur	2.302 ***	2.745 ***	1.603 *			
	(0.679)	(0.615)	(0.897)			
diff(lpricew_trop)				0.033	−0.038	0.043
				(0.039)	(0.084)	(0.068)
diff(lpricew_oak)				−0.898 ***	−0.820 ***	−0.920 ***
				(0.064)	(0.123)	(0.038)
diff(lgdp_const_eur)				4.095 ***	4.599 ***	−0.251
				(0.686)	(0.690)	(0.637)
Observations	432	288	144	408	264	120
R^2	0.271	0.321	0.364	0.527	0.504	0.642

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

The assessment as to whether tropical and oak lumber are substitute or complementary products is more plausible when their import volumes are of the same order of magnitude. This is true for many countries, but this is not the case in France which has a large domestic oak production and as a consequence imports small amounts of oak at higher prices (Figure A3). An indication of the ratio of tropical to oak lumber import is given in the shock models results (Tables 1 and 2). In general, we observe that the import demand for oak lumber behaves similarly to a more general sawnwood demand import model [12].

5. Summary and Conclusions

The EU Timber Regulation (EUTR) is a key element of the Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan aimed at curbing illegal logging and its associated trade. Due to the rather short time that the EUTR has been in force, there are yet no studies that have performed systematic, comprehensive statistical analysis as to impacts on international trade in timber products. This study aims to help fill this research gap by assessing whether the patterns of EU imports of hardwood timber products have changed as a result of the coming into force of the EUTR. In addition to the analysis itself, to the best of our knowledge the first attempt at a comprehensive statistical analysis of the effects of the EUTR, a major contribution of the paper is the procedure for tackling the issue of the frequent changes in tropical hardwood lumber product codes, in order to build as long and homogenous a time series as possible.

The cointegration intervention, or shock, models analysis, indicate—for most of the bilateral trade flows (EU member states imports) where we observe cointegration and a significant shock variable—that increasing import prices and decreasing import quantities of tropical hardwood lumber relative oak lumber. This is consistent with a predominant reduction of the supply of tropical timber in these cases. There are however notable exceptions from this pattern, in terms of coincedental decreases of prices and increases in import quantities of tropical sawnwod, which would instead be consistent with an increase in the supply of tropical timber in these cases. In addition, the model does not show any clear difference in results between VPA and non-VPA countries.

The results of the import demand models do not give a clear indication as to whether oak lumber is a complementary or substitute product to/for tropical hardwood sawnwood, and they do not give an unanimous picture as to any potential structural changes in demand elasticities after the entry into effect of the EUTR. It should be noted that price variables used in the demand model consider that the supply is infinitely elastic [12], but this assumption is a tad unrealistic, since the EUTR could be seen to introduce supply constraints, in the sense of costs of complying with the requirements of the legislation. An extension of this work could analyze the supply side of the market.

We estimate models before and after the EUTR start date respectively. However, changes in the market due to EUTR legislation are likely to happen gradually rather than discretely. Hence, market operators may have anticipated the introduction of the EUTR, as suggested by some studies [21]. Furthermore, the first legal cases of enforcement occurred several years after the EUTR entered into force. A growing body of legal proceedings on EUTR enforcement is likely to increase the dissuasive effect of the legislation, and to increase compliance of due diligence. These processes are ongoing, and their effects will be measurable over the next decade. It is therefore likely that the structural changes in demand and supply functions are not abrupt, but gradual, following a smooth transition from one model to a new post-EUTR model.

Even assuming that we have captured the most pertinent effects of the EUTR on EU imports of tropical hardwood sawnwood, we are not in a position to assess whether the regulation has been successful in curbing illegal logging and its associated trade. Thus, reduced supply of tropical timber to EU member states might indicate that exporters have seized exporting illegal timber to these destinations. However, this would not necessarily mean that illegal logging in the exporting nation has decreased, as the illegal timber could have been diverted to other less regulated markets, either abroad and/or domestic.

Further, it is important that the EUTR does not deter the export of legal timber products from developing countries to the EU. Addressing these issues also calls for a study of the supply of tropical timber products, in particular trade diversion, to complement the current analysis.

Author Contributions: Conceptualization, P.R. and R.J.; methodology, P.R. and R.J.; software, P.R.; validation, P.R. and R.J.; formal analysis, P.R.; data curation, P.R.; writing—original draft preparation, P.R. and R.J.; writing—review and editing, P.R. and R.J.; visualization, P.R. Both authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data and R scripts supporting the reported results can be found at https://doi.org/10.6084/m9.figshare.14519562, accessed on 28 April 2021, or https://gitlab.com/paulrougieux/eutr_trade_impact_sustainability/, accessed on 28 April 2021.

Acknowledgments: The work described in this paper has (though not constituting its official output) been carried out in the context of the JRC Biomass assessment study https://ec.europa.eu/knowledge4policy/projects-activities/jrc-biomass-study_en, accessed on 28 April 2021.

Conflicts of Interest: The authors declare no conflict of interest. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the European Commission. The scientific output does not imply a policy position of the European Commission.

Abbreviations

The following abbreviations are used in this manuscript:

ADF	Augmented Dickey Fuller
CN	Combined Nomenclature
FLEGT	Forest Law Enforcement, Governance and Trade
EUTR	European Union Timber Regulation

Appendix A. Extra Tables and Graphs

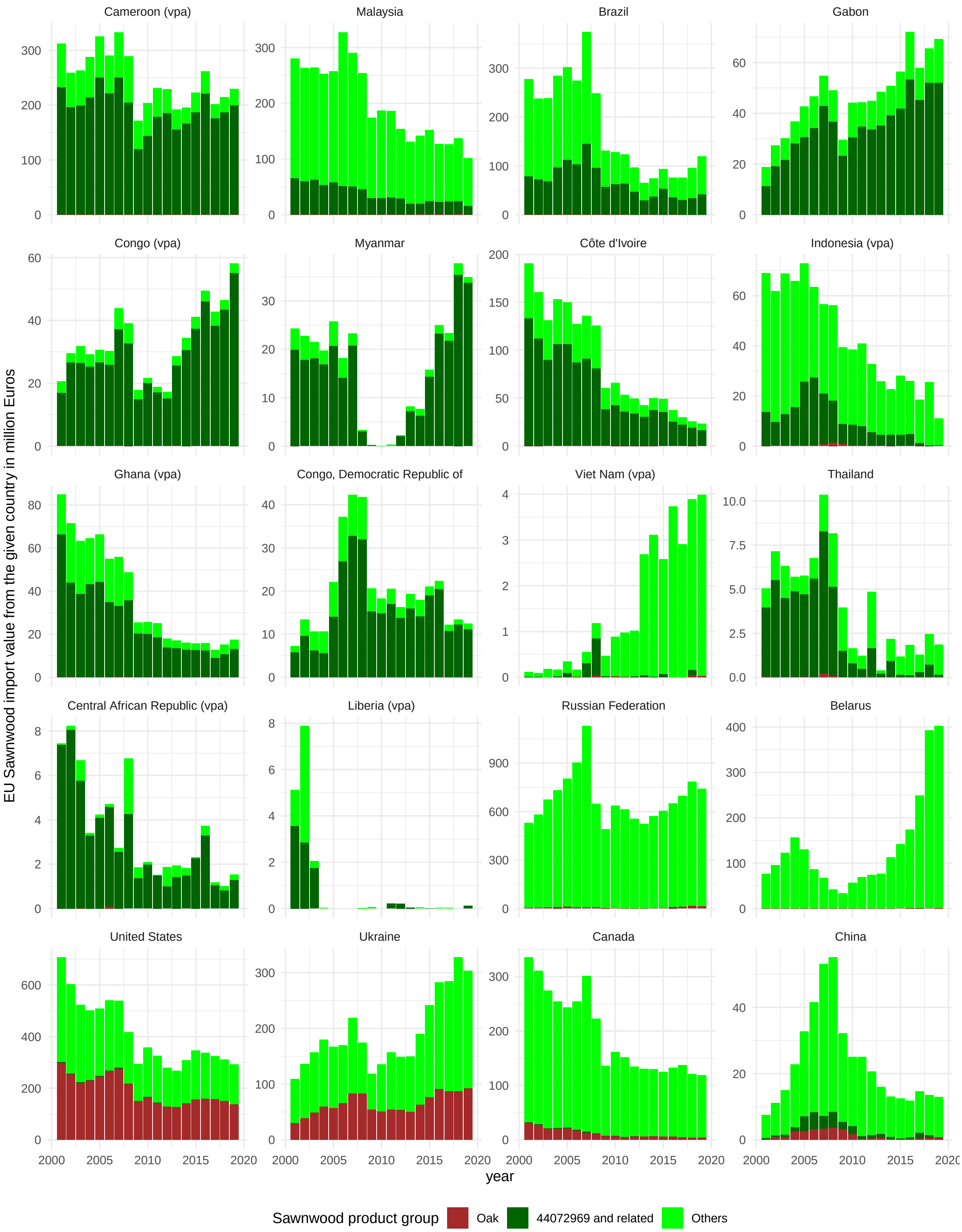

Figure A1. EU sawnwood imports from tropical countries and major temperate partner countries. EU = EU27 + UK.

Figure A2. Changes in EU tropical sawnwood imports for product codes related to 44072969. Other sawnwood of unknown classifiation under 440799 are plotted in the second column.

Table A1. Description of sawnwood product codes related to 44072969.

Code	Description
44072180	Meranti bakau, white seraya, yellow meranti, alen, keruing, ramin, kapur, teak, jongkong, merbau, jelutong and kempas, sawn or cut lengthwise, sliced or peeled, of a thickness of >6 mm (excl. such products planed, sanded, or finger-jointed)
44072190	Dark red meranti, light red meranti, meranti bakau, white lauan, white meranti, white seraya, yellow meranti, alen, keruing, ramin, kapur, teak, jongkong, merbau, jelutong, and kempas, sawn or cut lengthwise, sliced or barked, with a thickness of >6 mm (excl. planed, sanded, or finger-jointed)
44072260	Azobé, sawn or cut lengthwise, sliced or peeled, of a thickness of >6 mm (excl. such products planed, sanded, or finger-jointed)
44072280	Okoumé, obeche, sapelli, sipo, acajou d'Afrique, makoré, iroko, tiama, mansonia, ilomba, dibétou, and limba woods, sawn or cut lengthwise, sliced or peeled, of a thickness of >6 mm (excl. such products planed, sanded, or finger-jointed)
44072290	Okoume, obeche, sapele, utile, african mahogany, makore, iroko, tiama, mansonia, ilomba, dibetou, limba, and azobe, sawn or cut lengthwise, sliced or barked, with a thickness of > 6mm (excl. planed, sanded, or finger-jointed)
44072799	Sapelli, sawn, or chipped lengthwise, sliced or peeled, of a thickness of >6 mm (excl. planed, sanded, or end-jointed)
44072899	Iroko, sawn, or chipped lengthwise, sliced or peeled, of a thickness of >6 mm (excl. planed, sanded, or end-jointed)
44072960	Keruing, ramin, kapur, teak, jongkong, merbau, jelutong, kempas, okoumé, obeche, sipo, acajou d'Afrique, makoré, tiama, mansonia, ilomba, dibétou, limba, azobé, palissandre de Rio, palissandre de Para, and palissandre de rose, sawn or chipped lengthwise, sliced or peeled, of a thickness of >6 mm (excl. such products planed, sanded, or end-jointed)
44072961	Azobé, sawn or chipped lengthwise, sliced or peeled, of a thickness of >6 mm (excl. such products planed, sanded, or end-jointed)
44072968	Keruing, ramin, kapur, teak, jongkong, merbau, jelutong, kempas, okoumé, obeche, sipo, acajou d'Afrique, makoré, tiama, mansonia, ilomba, dibétou, limba, palissandre de Rio, palissandre de Para, and palissandre de rose, sawn or chipped lengthwise, sliced or peeled, of a thickness of >6 mm (excl. such products planed, sanded, or end-jointed)
44072969	Keruing, ramin, kapur, teak, jongkong, merbau, jelutong, kempas, okoumé, obeche, sapelli, sipo, acajou d'Afrique, makoré, iroko, tiama, mansonia, ilomba, dibétou, limba, palissandre de Rio, palissandre de Para, and palissandre de rose, sawn or chipped lengthwise, sliced or peeled, of a thickness of >6 mm (excl. such products planed, sanded, or end-jointed)
44072995	Abura, afrormosia, ako, andiroba, aningré, avodiré, balau, bossé clair, bossé foncé, cativo, cedro, dabema, doussié, framiré, freijo, fromager, fuma, geronggang, ipé, jaboty, jequitiba, kosipo, kotibé, koto, louro, maçaranduba, mahogany (excl. "*Swietenia* spp."), mandioqueira, mengkulang, merawan, merpauh, mersawa, moabi, niangon, nyatoh, onzabili, orey, ovengkol, ozigo, padauk, paldao, palissandre de Guatemala, pau Amarelo, pau marfim, pulai, punah, quaruba, saqui-saqui, sepetir, sucupira, suren, tauari, tola, keruing, ramin, kapur, teak, jongkong, merbau, jelutong, kempas, okoumé, obeche, sipo, acajou d'Afrique, makoré, tiama, mansonia, ilomba, dibétou, limba, azobé, palissandre de Rio, palissandre de Para, and palissandre de Rose, sawn or chipped lengthwise, sliced or peeled, of a thickness of >6 mm (excl. end-jointed, planed, and sanded)
44072999	Abura, afrormosia, ako, andiroba, aningré, avodiré, balau, bossé clair, bossé foncé, cativo, cedro, dabema, doussié, framiré, freijo, fromager, fuma, geronggang, ipé, jaboty, jequitiba, kosipo, kotibé, koto, louro, maçaranduba, mahogany (excl. "*Swietenia* spp."), mengkulang, merawan, merpauh, mersawa, moabi, niangon, nyatoh, onzabili, orey, ovengkol, ozigo, padauk, paldao, palissandre de Guatemala, pau marfim, pulai, punah, saqui-saqui, sepetir, sucupira, suren, and tola, sawn or chipped lengthwise, sliced or peeled, of a thickness >6 mm (excl. finger-jointed, planed, or sanded)

Table A2. Number of missing data points in the monthly imports of tropical sawnwood related to 44072969. Time series between 2001 and 2019. No value means a total absence of data.

	Brazil	Cameroon	Central African Republic	China	Congo	Côte d'Ivoire	Gabon	Ghana	Indonesia	Malaysia	Myanmar	Thailand	Viet Nam	Congo, Democratic Republic of	Liberia
Austria	179	207	227	212	215	212	227	165	167	214	223	227	227		
Belgium	0	0	102	181	34	2	6	6	56	1	128	202	225	2	226
Bulgaria	227	193		226	220	208	225	211	226	227				227	
Croatia	200	104	227	218	201	169	215	157	194	203	173	223	227	212	227
Cyprus	204	148	227	227	219	103	199	190		223	227			166	
Czech Republic	181	170	226	227	202	225		182	167	219	215	226		225	227
Denmark	0	49	223	196	49	174	206	85	124	53	94	174	224	202	227
Estonia		216			225	223		196	221		225	224		226	
Finland	206	167		222	184	172	220	188	127	132	202	184	227	224	
France	0	0	132	169	1	6	0	9	46	0	140	210	222	95	185
Germany	29	0	201	192	46	26	100	0	42	17	91	174	225	157	224
Greece	191	14	227	215	192	2	152	135	171	156	175	217		204	225
Hungary	225	219		223	224	221	225	214	212	222	225				
Ireland	206	3		219	171	50	216	108	222	215		225		216	
Italy	65	0	174	103	9	0	0	9	87	6	49	145	213	65	210
Latvia	225				227									225	
Lithuania	207	155	226	220	214	199	226	186	144	215	223			218	
Luxembourg	227	227												227	
Malta	221	138		224	220	136	222	159		226	226	223		219	
Netherlands	0	0	218	205	96	14	39	54	75	0	114	129	226	125	223
Poland	125	111	221	219	79	112	171	154	82	138	148	220		187	
Portugal	0	1	200	224	33	77	14	193	222	225	223			52	227
Romania	225	157	221	225	202	181	217	214	206	215			226	223	
Slovakia	223	219	225		221	227		219	223	227	221			227	
Slovenia	199	191	226	221	222	212	224	211	211	222	180	224	227	220	227
Spain	2	0	99	200	21	4	39	83	146	186	186	211		99	222
Sweden	172	201		205	202	214	222	185	126	108	110	192	226		
Utd. Kingdom	119	0	206	193	26	2	198	0	116	0	145	206	227	84	225

Table A3. Average yearly imports of tropical sawnwood related to 44072969 over the period 2010–2019 in thousand euros.

	Brazil	Cameroon	Central African Republic	China	Congo	Côte d'Ivoire	Gabon	Ghana	Indonesia	Malaysia	Myanmar	Thailand	Viet Nam	Congo, Democratic Republic of	Liberia
Austria	78	31		92	113		34		38	153		18	155		
Belgium	9967	75,169	1017	178	9949	8501	6362	23,497	1267	675	55	1802	957	78	
Bulgaria	1	59		20	34		38		24						
Croatia	29	181		23	25	23	64	31	19	15		42	1009	36	
Cyprus	29	329			58	183	244	295	67						
Czech Republic	51	49		18	197	14	11		29	25	7	13	929		
Denmark	3190	697	22	95	1212	120	52	39	249	246		648	1101	62	
Estonia		81			60	15	27		268						
Finland	26	178		1	190	30			10	177		432	274		
France	14,778	19,207	217	94	5616	507	1873	2756	1876	1307	112	4403	108	14	27
Germany	1177	5511	77	90	1200	751	1109	231	5875	568		3567	3321	206	
Greece	57	1268		120	65	34	1940	132	298	116	15	128	726	63	
Hungary							0					2			
Ireland	27	8624		24	315	174	659	80	83			89		33	
Italy	308	17,472	100	448	1492	543	6674	10,342	866	242		2656	8673	115	4
Latvia															
Lithuania	24	110		2	25	19	37		52	523		70			
Luxembourg															
Malta		407		60	60	51	85	55	90					47	
Netherlands	4700	10,728	49	130	2402	1523	1774	1638	345	246		5455	1255	467	113
Poland	100	175	62	18	360	100	115	83	38	353		111	512	99	
Portugal	4528	4067	240	11	1343	630	214	1938	48			46	112		
Romania	9	97		79	104		19	32	36	117		36			0
Slovakia	38	51	20			10									
Slovenia	142	60		37	125	40	26	49		21		19	159	12	
Spain	4377	16,352	226	46	909	365	2424	858	175	40		58	266		
Sweden	88	39							10	223		280	517	0	67
Utd. Kingdom	195	19,235	47	142	7862	2147	6107	191	2148	238	57	4329	299	31	19

Table A4. Augmented Dickey–Fuller test of the monthly price series of tropical sawnwood over the period 2001–2013. Prices are transformed to natural logarithms. I(1) indicate where the null hypothesis of stationarity is rejected for *p*-values above 0.05.

Reporter	Partner T	ADF Test	Lag Order	*p* Value	Stationarity	N
Belgium	Côte d'Ivoire	−4.595	5	0.010	I(0)	146
France	Gabon	−4.386	5	0.010	I(0)	146
Ireland	Cameroon	−4.238	5	0.010	I(0)	146
Italy	Ghana	−4.170	5	0.010	I(0)	146
Denmark	Brazil	−4.080	5	0.010	I(0)	146
Germany	Malaysia	−4.040	5	0.010	I(0)	146
Utd. Kingdom	Ghana	−3.997	5	0.011	I(0)	146
Portugal	Gabon	−3.942	5	0.014	I(0)	146
Germany	Ghana	−3.914	5	0.015	I(0)	146
Italy	Congo	−3.880	5	0.017	I(0)	146
Greece	Cameroon	−3.851	5	0.018	I(0)	146
France	Côte d'Ivoire	−3.752	5	0.023	I(0)	146
Belgium	Congo DRC	−3.669	5	0.030	I(0)	146
France	Brazil	−3.630	5	0.033	I(0)	146
Utd. Kingdom	Malaysia	−3.591	5	0.037	I(0)	146
Germany	Cameroon	−3.568	5	0.039	I(0)	146
Italy	Malaysia	−3.562	5	0.039	I(0)	146
Belgium	Malaysia	−3.548	5	0.041	I(0)	146
Utd. Kingdom	Côte d'Ivoire	−3.543	5	0.041	I(0)	146
Netherlands	Brazil	−3.501	5	0.045	I(0)	146
Italy	Cameroon	−3.452	5	0.049	I(0)	146
Spain	Cameroon	−3.412	5	0.055	I(1)	146
France	Congo	−3.380	5	0.061	I(1)	146
France	Malaysia	−3.334	5	0.068	I(1)	146
Spain	Brazil	−3.198	5	0.091	I(1)	146
Belgium	Ghana	−3.150	5	0.099	I(1)	146
Belgium	Brazil	−3.082	5	0.126	I(1)	146
Greece	Côte d'Ivoire	−2.839	5	0.227	I(1)	146
Netherlands	Côte d'Ivoire	−2.748	5	0.265	I(1)	146
Netherlands	Cameroon	−2.700	5	0.285	I(1)	146
Spain	Côte d'Ivoire	−2.686	5	0.291	I(1)	146
France	Ghana	−2.659	5	0.302	I(1)	146
Belgium	Gabon	−2.510	5	0.364	I(1)	146
Netherlands	Malaysia	−2.315	5	0.445	I(1)	146
Portugal	Brazil	−2.252	5	0.472	I(1)	146
Italy	Gabon	−2.172	5	0.505	I(1)	146
Utd. Kingdom	Cameroon	−2.143	5	0.517	I(1)	146
Italy	Côte d'Ivoire	−2.048	5	0.556	I(1)	146
France	Cameroon	−1.949	5	0.598	I(1)	146
Portugal	Cameroon	−1.915	5	0.612	I(1)	146
Belgium	Cameroon	−1.897	5	0.619	I(1)	146

Table A5. Augmented Dickey–Fuller test of the monthly price series of oak sawnwood over the period 2001–2013. Prices are transformed to natural logarithms. I(1) indicate where the null hypothesis of stationarity is rejected for *p*-values above 0.05.

Reporter	Partner T	ADF Test	Lag Order	*p* Value	Stationarity	N
Greece	United States	−3.729	5	0.024	I(0)	146
Portugal	United States	−3.716	5	0.025	I(0)	146
Belgium	United States	−3.613	5	0.035	I(0)	146
Utd. Kingdom	United States	−3.540	5	0.041	I(0)	146
Spain	United States	−3.445	5	0.050	I(0)	146
Italy	United States	−3.223	5	0.087	I(1)	146
Ireland	United States	−3.122	5	0.109	I(1)	146
Germany	United States	−2.943	5	0.184	I(1)	146
France	United States	−2.897	5	0.203	I(1)	146
Denmark	United States	−2.623	5	0.317	I(1)	146
Netherlands	United States	−2.446	5	0.391	I(1)	146

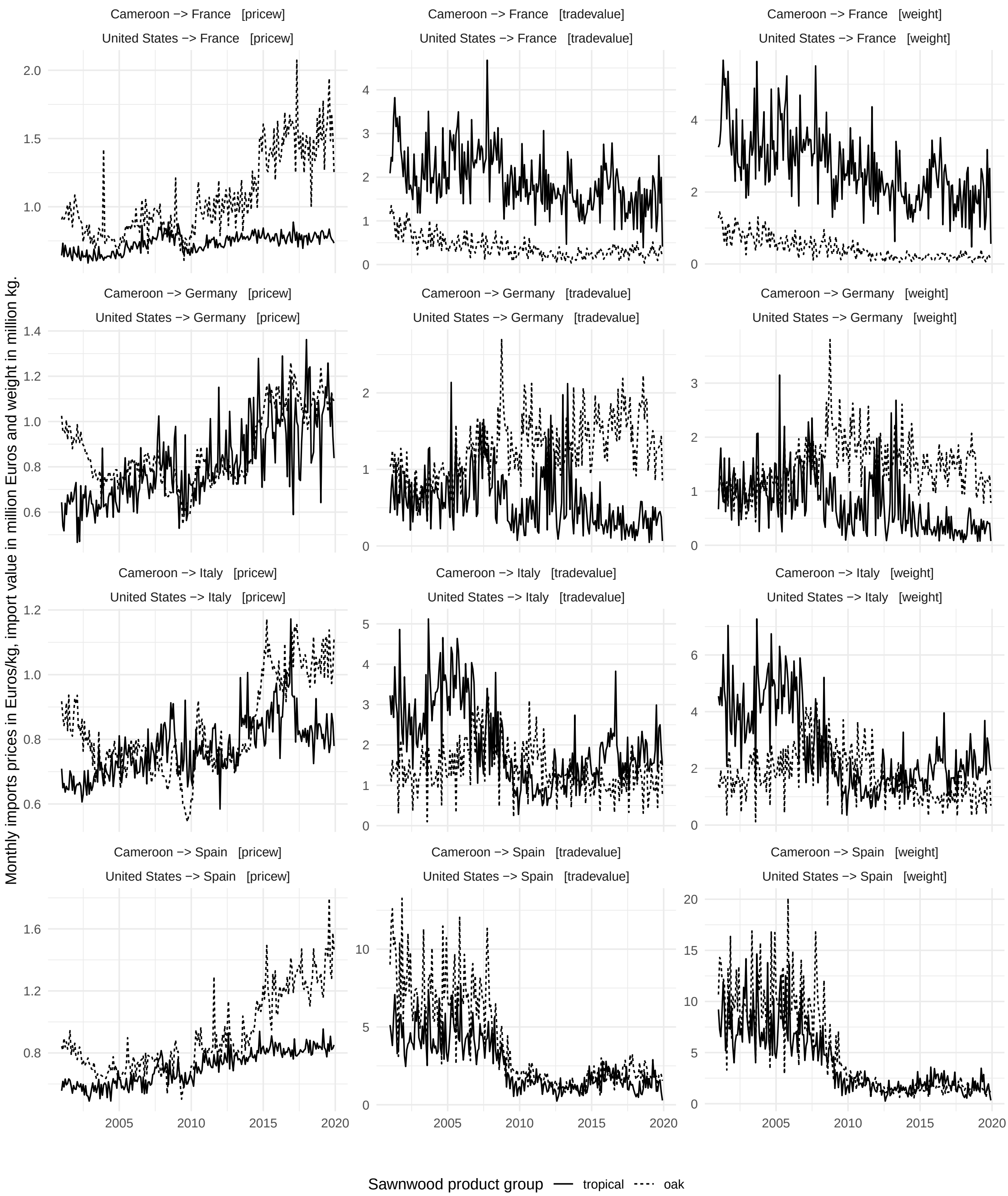

Figure A3. Comparison of tropical sawnwood imports from Cameroon and oak sawnwood imports the United States. Tropical products related to the CN code 44072969 were used in the cointegration analysis.

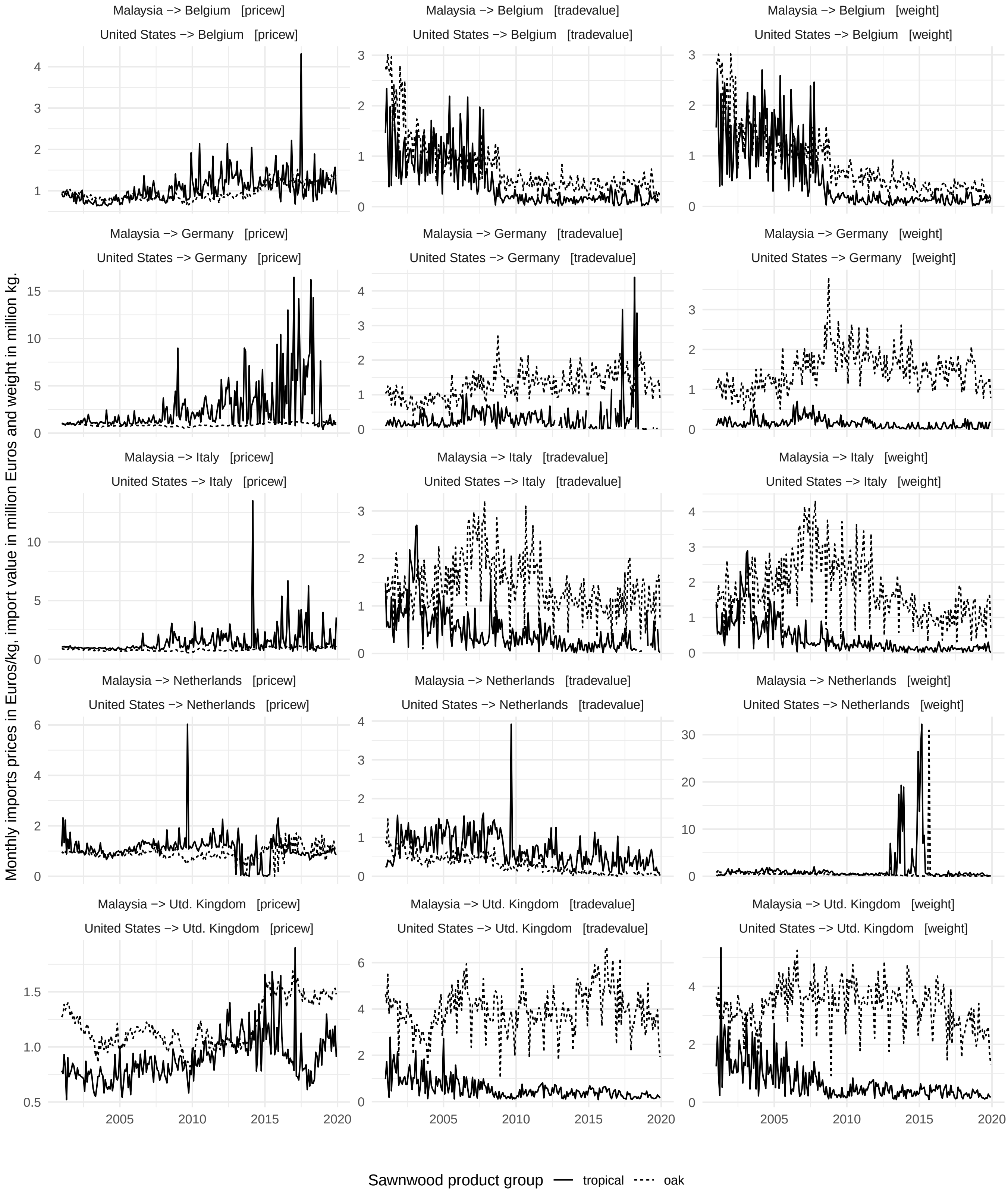

Figure A4. Comparison of tropical sawnwood imports from Malaysia and oak sawn wood imports from the United States.

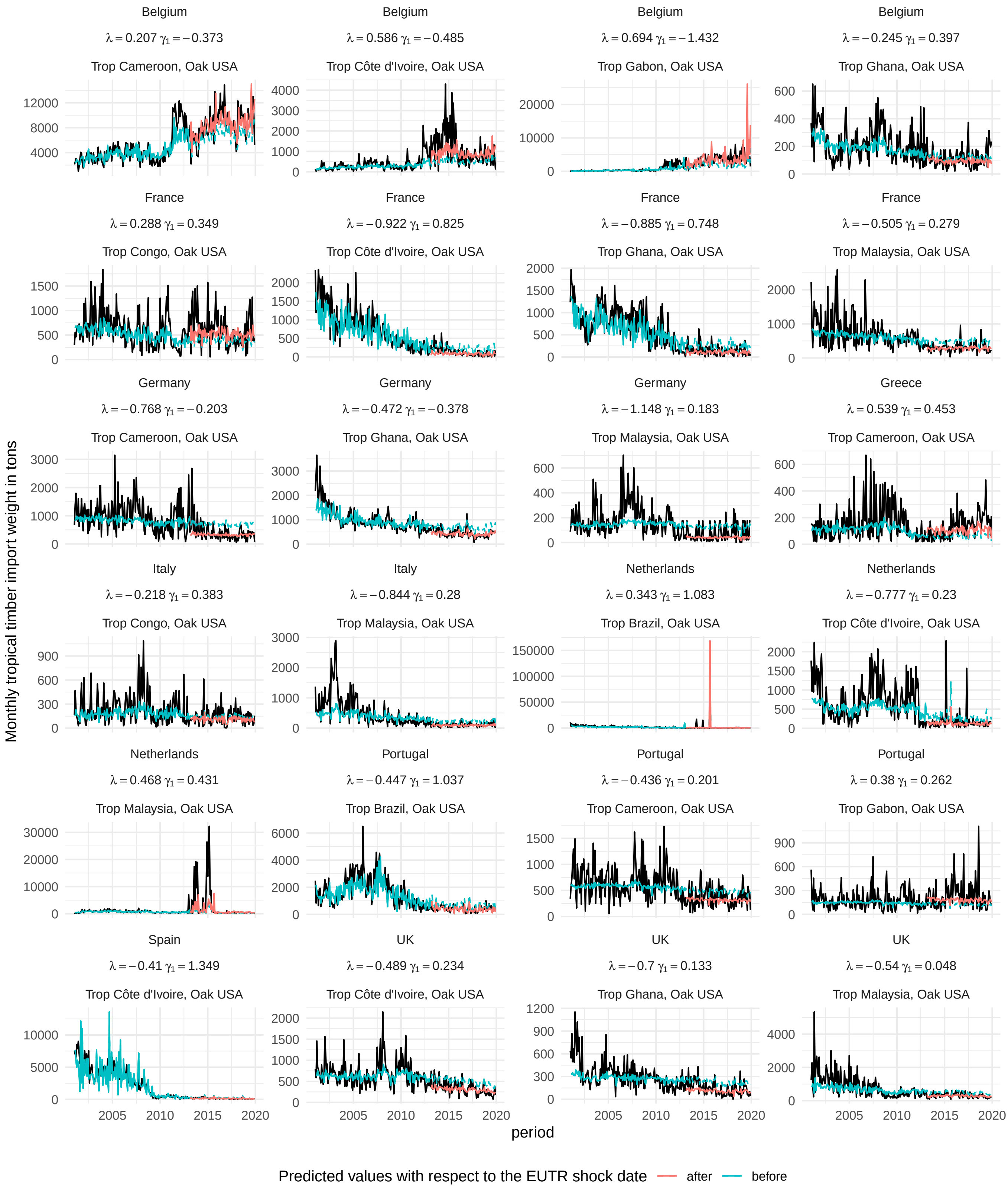

Figure A5. Observed versus predicted tropical sawnwood import weights based on the shock model. Only country pairs with absolute values of lambda greater than 0.2 are displayed here.

Table A6. Descriptive statistics of the balanced panel of tropical and oak sawnwood import demand over the period 2002–2019. GDP in constant euros of 2015.

	Tropical Imports		Tropical Prices		Oak Imports		Oak Prices		GDP	
	1000 tons/year		Euros/Ton		1000 tons/year		Euros/Ton		Billion Euros	
Reporter	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
Austria	1	7	855	1851	48	114	350	722	289	374
Belgium	54	250	668	1172	11	85	553	2943	339	444
Bulgaria	0	1	616	1489	1	18	247	581	30	52
Croatia	1	3	738	2778	4	53	294	612	38	51
Czech Republic	1	2	706	3488	2	24	403	4037	119	193
Denmark	9	25	859	1840	7	23	857	1295	240	305
Estonia	0	1	958	2549	1	9	452	1010	14	25
Finland	0	4	1178	3028	4	23	724	1412	184	230
France	49	206	584	933	9	31	724	2859	1902	2349
Germany	28	85	738	1476	64	97	422	959	2575	3232
Greece	2	11	756	1540	4	40	535	872	175	240
Hungary	0	1	743	1597	12	39	158	625	90	132
Ireland	5	42	668	1154	3	13	1001	1583	160	335
Italy	46	167	735	1264	99	180	507	760	1643	1795
Latvia	0	0	930	13,865	1	7	353	1255	16	28
Lithuania	0	3	491	1662	9	91	320	639	23	43
Netherlands	54	247	212	986	29	532	85	1383	596	755
Poland	1	14	799	1693	40	116	229	503	262	513
Portugal	13	62	491	769	13	39	645	1054	175	200
Romania	0	1	530	1544	2	22	324	837	102	196
Slovenia	0	1	1188	4646	16	42	299	741	31	45
Spain	26	257	557	963	25	165	557	1078	935	1194
Sweden	0	11	918	5419	5	54	661	1354	341	492
Utd. Kingdom	43	96	689	1183	62	106	706	1510	2143	2806

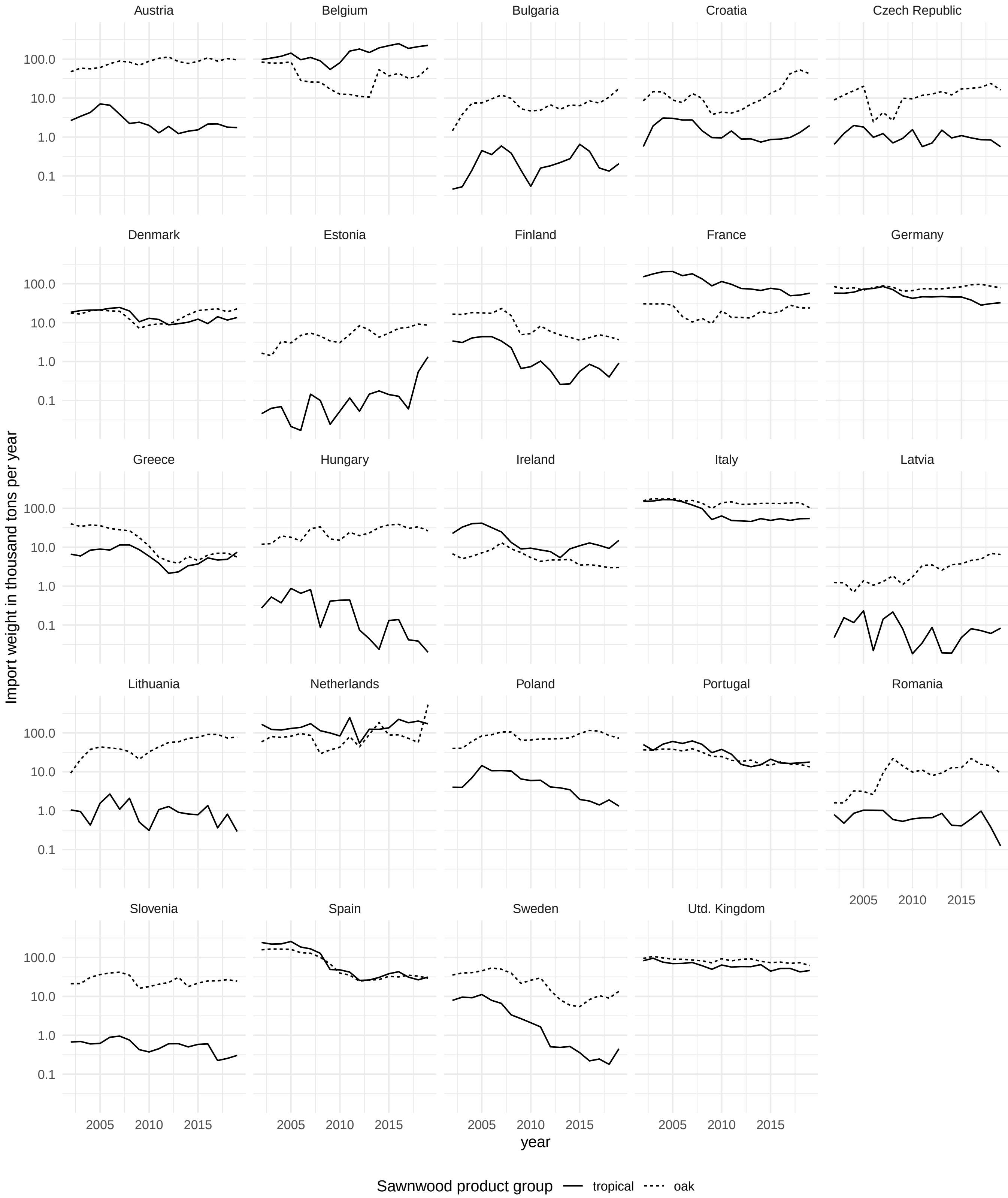

Figure A6. Tropical sawnwood and oak sanwood imports from the balanced panel dataset used in the demand model.

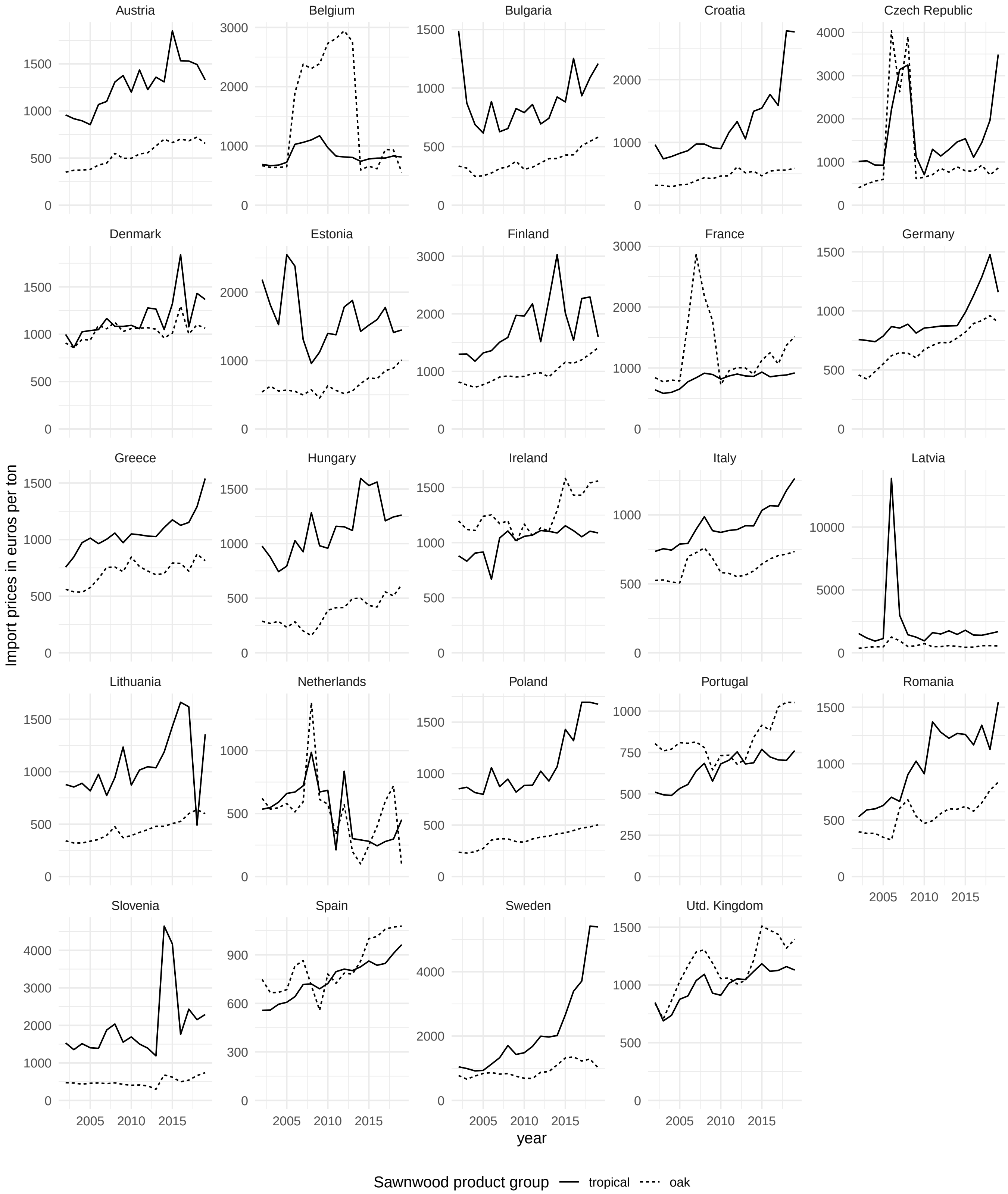

Figure A7. Tropical sawnwood and oak sawnwood prices from the balanced panel dataset used in the demand model.

Table A7. Augmented Dickey Fuller tests of the individual time series from the balanced panel dataset.

Reporter	Lweight_Trop	Lpricew_Trop	Lpricew_oak	Lgdp_Const_Eur
Austria	0.542 I(1)	0.704 I(1)	0.859 I(1)	0.464 I(1)
Belgium	0.645 I(1)	0.211 I(1)	0.635 I(1)	0.433 I(1)
Bulgaria	0.178 I(1)	0.199 I(1)	0.360 I(1)	0.237 I(1)
Croatia	0.962 I(1)	0.978 I(1)	0.632 I(1)	0.446 I(1)
Czech Republic	0.495 I(1)	0.427 I(1)	0.051 I(1)	0.229 I(1)
Denmark	0.907 I(1)	0.335 I(1)	0.398 I(1)	0.799 I(1)
Estonia	0.193 I(1)	0.719 I(1)	0.963 I(1)	0.417 I(1)
Finland	0.990 I(1)	0.949 I(1)	0.934 I(1)	0.477 I(1)
France	0.498 I(1)	0.277 I(1)	0.242 I(1)	0.596 I(1)
Germany	0.049 I(0)	0.122 I(1)	0.010 I(0)	0.458 I(1)
Greece	0.833 I(1)	0.980 I(1)	0.537 I(1)	0.437 I(1)
Hungary	0.010 I(0)	0.461 I(1)	0.398 I(1)	0.840 I(1)
Ireland	0.920 I(1)	0.807 I(1)	0.859 I(1)	0.890 I(1)
Italy	0.871 I(1)	0.817 I(1)	0.164 I(1)	0.749 I(1)
Latvia	0.615 I(1)	0.089 I(1)	0.323 I(1)	0.243 I(1)
Lithuania	0.209 I(1)	0.133 I(1)	0.305 I(1)	0.296 I(1)
Netherlands	0.754 I(1)	0.577 I(1)	0.261 I(1)	0.586 I(1)
Poland	0.010 I(0)	0.934 I(1)	0.010 I(0)	0.644 I(1)
Portugal	0.765 I(1)	0.754 I(1)	0.976 I(1)	0.746 I(1)
Romania	0.294 I(1)	0.956 I(1)	0.299 I(1)	0.467 I(1)
Slovenia	0.366 I(1)	0.404 I(1)	0.898 I(1)	0.567 I(1)
Spain	0.926 I(1)	0.812 I(1)	0.651 I(1)	0.370 I(1)
Sweden	0.864 I(1)	0.871 I(1)	0.456 I(1)	0.518 I(1)
Utd. Kingdom	0.434 I(1)	0.460 I(1)	0.097 I(1)	0.471 I(1)

Table A8. Maddala and Wu, Levin–Lin–Chu, and Hadri panel stationarity tests of the demand model variables.

Variable	Madwu	Levinlin	Hadri
lweight_trop	0.000 I(0)	0.021 I(0)	0.000 I(1)
lpricew_trop	0.000 I(0)	0.081 I(1)	0.000 I(1)
lpricew_oak	0.003 I(0)	0.070 I(1)	0.000 I(1)
lgdp_const_eur	0.625 I(1)	0.020 I(0)	0.000 I(1)

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