Essays on International Timber Products Trade

by

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Abstract

During the last decade, the production and trade of timber products have gone through rapid change due to the implementation of several new policies and regulations. Specifically, one of the world's largest exporters of coniferous logs, Russia, increased its restrictions on log exports to stimulate domestic lumber production since 2007. European Union (EU) has implemented the Forest Law Enforcement, Governance, and Trade (FLEGT) Action Plan that is aimed at combating illegal logging and improving forest governance from both demand and supply sides. Understanding the effectiveness of these measures is critical for policy assessment and instructive for policy improvements.

In the first study, we use a Muth-type equilibrium displacement model to investigate the market and welfare impacts of a Russian log export tax, utilizing a vertical linkage between log and lumber markets and considering factor substitution. Our theoretical analysis indicates that the negative effects of log export tax on equilibrium price for log producers would be underestimated when input factors are gross substitutes. Empirical simulations show that the burden of Russian log export tax is shared almost equally between foreign log buyers and domestic log producers and that the tax induces an increase in domestic lumber production in Russia. The sum of the welfare gains for Russian lumber consumers and lumber producers and the export tax revenue exceeds the welfare losses experienced in the Russian logging sector.

In the second study, we use quarterly trade data to quantify the impacts of the demand side measure, the EU Timber Regulation (EUTR), on import quantities by EU Member State and by product. Our results show that most north and central European countries significantly decreased their imports of tropical and temperate timber products. Furthermore, the United Kingdom and some southeast and south-central European countries significantly reduced their imports of tropical timber products but increased their imports of temperate plywood. However, significant increases in the imports of tropical logs have been observed in western and north-central European countries.

In the third study, we take Ghana as a study case to analyze the impact of a Voluntary Partnership Agreement (VPA) on exports to the EU and other importer countries separately. Our gravity model estimation results show that Ghana increased its exports of roundwood to both the EU and the other countries. Furthermore, its exports of sawnwood, plywood, and veneer sheets decreased significantly to the EU. However, there were no significant effects on Ghana's exports of these processed timber products to the non-EU destinations.

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List of Abbreviations

EU	European Union
EC	European Commission
FAO	Food and Agricultural Organization
ROW	Rest-of-the-World
US	United States
EUTR	EU Timber Regulation
FLEGT	Forest Law Enforcement, Governance, and Trade (Action Plan)
LAA	Lacey Act Amendment of 2008
LAS	Legality Assurance System
VPA	Voluntary Partnership Agreement
CRS	Constant Returns to Scale
GDP	Gross Domestic Product
DF-GLS	Dickey-Fuller Generalized Least Squares
ECM	Error Correction Model
EDM	Equilibrium Displacement Model
OLS	Ordinary Least Squares
PPML	Poisson Pseudo-Maximum Likelihood
2SLS	Two-Stage Least Squares
SUR	Seemingly Unrelated Regression

Chapter 1. Introduction

During the last decade, the production and trade of timber products have gone through rapid change due to the implementation of several new policies and regulations. This dissertation analyzes the economic impacts of Russian log export tax and global efforts in curbing illegal logging. The effectiveness of these policies is instructive to other similar measures.

International trade of coniferous forest products has gone through huge market adjustment during the last decade, as one of the world's largest exporters of coniferous logs, Russia, increased its restrictions on exports. By 2006, the value of Russian softwood log exports reached 36.4 million m^3 and contributed to 44.5% of the worlds' total softwood log exports (FAO, 2016). To stimulate domestic production of lumber, Russia imposed an ad valorem tax on log exports beginning January 1, 2007. As a result, there has been a dramatic decline in the exports of Russian softwood logs to 12.4 million m^3 in 2013 (FAO, 2016). The market distortions brought by the tax is intertwined considering the inter-relationship between logs and lumber. As Russia's application for membership in the World Trade Organization was accepted in August 2012, it uses more nontax barriers to limit log exports and support domestic lumber processing (Simeone, 2012). Considering Russia's leading role in the exports of softwood logs and lumber, the incidence of the tax is instructive for assessing and predicting its impact on international trade flows of softwood logs and lumber.

Meanwhile, illegal logging is prevalent on hardwood forest products especially in tropical countries (Elias, 2012). Tropical deforestation has nearly cut tropical forests in half over the last

60-70 years (FAO, 2016). Even between 1990 and 2005 when the rate of deforestation has slowed down, 63 tropical countries still lost 8.3% of their total forest area, at an annual rate of 0.57% (Tropical Rainforests, 2016). Tropical deforestation has significant negative impacts on the life of local people, biodiversity, and climate. The causes of tropical deforestation have been attributed to poverty, agricultural and infrastructure expansion, national debt, insecure property rights, poor governance, and lack of payment for ecosystem services.

Recently, the international community has increased their awareness and taken various measures to curb illegal logging. Here we focus on the measures directly related to international trade. European Union (EU) has implemented the FLEGT (Forest Law Enforcement, Governance, and Trade) Action Plan that is aimed at combating illegal logging and improving forest governance. The first part of FLEGT is called the EU Timber Regulation, which is similar to the Lacey Act Amendment of 2008 (LAA) in the United States and prohibits operators in EU member states from placing illegally harvested timber products onto the EU market. This part came into force on March 3, 2013. The second part is Voluntary Partnership Agreements (VPAs) between the EU and individual tropical countries. Six countries—Cameroon, Central Africa, Ghana, Indonesia, Liberia, and the Republic of Congo—have signed a VPA with the EU and are currently developing and implementing the systems needed to control, verify and license legal timber. These countries are known as "VPA Partner Countries". The VPAs are implementations targeting the supply side. A VPA partner country is expected to guarantee that wood exported to the EU comes from legal sources. The EU provides assistance for the partner country to develop a viable timber tracking and licensing system, and in strengthening national governance capacity, as large civil society participation is required (Jonsson et al., 2015). However, the initiation process takes a long time for both sides to negotiate on the partnership. Ghana was among the first countries to initiate VPA negotiations with the EU in December 2006, and the VPA was signed in November 2009 and ratified in March 2010.

In general, the demand measures are expected to reduce the imports of tropical timber products which may contain high rates of illegal logging, while temperate timber products may fill the resulting gap in timber supply (Jonsson et al., 2015). Some evaluation reports describe the substitution of temperate timber and alternative materials for tropical hardwoods in major importing markets (Goetzl and Ekström, 2007; Villazón, 2009). For the supply side measures, if carried out effectively, the export supply curve from the VPA partner countries to the EU are projected to shift to the left. Therefore, theoretically, Ghana's export price of timber products will increase and quantities exported to the EU partner will decrease. However, producers in suspected source countries could have redirected their illegal timber products to other nations without comparable trade measures. The trade impacts brought by the actions should be assessed from a global perspective. Policy makers as well as countries expressing interests in curbing illegal logging, need to know exactly the impact and effectiveness of these measures.

Thus, the overall objective of this study is to quantitively measure the effectiveness of recent regulations from the perspective of international trade of softwood and hardwood timber products. Specifically, we measure the effects of Russian log export tax on the trade of softwood logs and lumber as it is one of the world's largest suppliers. The effects of the EUTR and VPA will be focused on the trade of hardwood timber products where illegal logging are prevalent. Several evaluation reports have draw constructive conclusions on the effects of FLEGT through literature review and surveys (e.g. Jonsson et al., 2015; European Commission, 2016). However, except Prestemon (2015), there are rare studies using econometric models to rule out the confounding influence of other macroeconomic factors and to arrive precise conclusions regarding the impacts of recent trade regulations on international timber products.

Under this overall objective, there are three specific objectives. Objective 1 is to measure the incidence of Russian log export tax along the vertical marketing channel from logs to lumber using a Muth-type equilibrium displacement model (EDM). The log and lumber markets are incorporated in one structural model through production and factor demand functions. Russia is a net exporter of both logs and lumber, which is characterized by the excess demand of the rest-of-the-world (ROW). Moreover, the domestic infant industry, the lumber mills, is supposed to receive an indirect subsidy from lower domestic log price induced by the log export tax. With the above settings, the initial equilibrium is set up in vertical and international channels. Data for Russian production, consumption, and export in logs and lumber are from FAO (FAO, 2016). We have 23 years of data from 1992 to 2014. The incidence of the tax is solved by introducing the tax rate as an exogenous change in the initial equilibrium.

Objective 2 is to quantify the effects of EUTR on the import demand of hardwood timber by product and the EU member state. Specifically, we estimate the impacts of EUTR on the quantities imported by each member state in terms of six products, i.e. tropical and temperate roundwood, tropical and temperate lumber, and tropical and temperate plywood. In this way, we can detect the substitution of temperate timber for tropical timber on the national level and the possible diversion of exports of tropical timber to destinations with a relatively laxer regulatory framework within the EU markets. Multivariate regressive models of individual time series are adopted to cohere with economic theory and to isolate the confounding influence of other macroeconomic factors. We use the two-step approach by Engle and Granger (1987) with quarterly time series data starting from 1999Q1 to evaluate the cointegration and long-run equilibrium relationship, with error correction models detecting the transitory effects of EUTR and its adjustment to equilibrium.

Objective 3 is to investigate and quantify the impacts of VPA using gravity model analysis. We limit the analysis to Ghana's exports as it is the first exporter ratifying the VPA, and there are enough observations for econometric analysis. The investigated four timber products are roundwood, sawnwood, plywood, and venner sheets as coverd under the VPA. The main export destinations are selected to collectively import over 80% of the total exports. In this way, we can detect the impacts of VPA on Ghana's exports to the EU communities and the possible diversion of exports to destinations outside the VPA regulation.

Chapter 2. Incidence of Russian Log Export Tax: A Vertical Log-lumber Model

Abstract

In 2007, Russia imposed an ad valorem tax on its log exports. In this paper, we use a Muth-type equilibrium displacement model to investigate the market and welfare impacts of this tax, utilizing a vertical linkage between log and lumber markets and considering factor substitution. Our theoretical analysis indicates that, without considering the vertical linkage, the negative effects of log export tax on equilibrium price for log producers is underestimated log and processing services are gross substitutes, and the direction of bias is uncertain when they are gross complements. Empirical simulations show that the burden of Russian log export tax is shared almost equally between foreign log buyers and domestic log producers and that the tax increases domestic lumber production. Further, the marginal effect of the log export tax on domestic lumber production decreases as Russian domestic demand share of logs increases. Overall, the welfare gains for Russian lumber consumers, lumber producers (quasi-rents to processing services), and tax revenue exceed the loss in its logging sector.

Keywords: Log export tax, vertical market, welfare analysis, Muth-type equilibrium displacement model, factor substitution.

1. Introduction

Russia is one of the world's largest exporters of coniferous logs. In 2006, its log exports reached 36.4 million m^3, which was more than six times in 1992 and contributed to 44.5% of the world's total softwood log exports (FAO, 2016). However, the vast forest resources in Russia have not contributed significantly to the country's economic growth because of lack of investments and low level of resource utilization in its forest sector (Torniainen et al., 2006). To stimulate domestic lumber production, Russia imposed an ad valorem export tax of 6.5% on January 1, 2007, rising to 20% on July 1, 2007 and 25% on April 1, 2008 (van Kooten and Johnston, 2014). As a result, Russian softwood log exports declined drastically to 12.4 million m^3 in 2013 (FAO, 2016).

The purpose of this chapter is to estimate the incidence of this tax and to assess its effectiveness. The net benefits of this tax on Russian economy depend on the way in which benefits and costs are distributed among log producers, lumber producers, and log and lumber consumers in Russia and overseas. Four features of the Russian log markets are important in this context. First, because Russia is the largest exporter of coniferous logs, an export tax would affect foreign log buyers. Second, unless the export demand for Russian logs is perfectly inelastic, part of the export tax would be borne by its domestic log producers. Third, the change in the price of one input factor (logs) influences Russian lumber production. As Russia exports more than half of its lumber production, foreign lumber buyers would be indirectly influenced by the implementation of Russian log export tax. Finally and perhaps importantly, reducing domestic log prices lead to changes in the economic rate of substitution between factor inputs in lumber production, which has a feedback effect on domestic log demand. Neglecting factor substitution may cause biased estimations on the price, production, and welfare effects of the log export tax.

Simeone (2012) and Yuri et al. (2013) look into Russian market share change in international log markets before and after the implementation of log export tax. Solberg et al. (2010) use a global forest sector model (EFI-GTM) to predict the Russian and global forest product markets towards 2020 under alternative tax levels. van Kooten and Johnston (2014) estimate the market effects of Russian log export tax by developing an integrated log-lumber trade model from a global perspective and using simulations. Their main conclusion is that liberation of the log export tax increases Russian welfare. This means that the tax indeed has caused welfare loss to Russia, which is contrary to the common economic understanding that a tax on exports is suboptimal for a country with international market power.

In this study, we use a Muth-type equilibrium displacement model (EDM) to measure the incidence of Russian log export tax based on a vertical log-lumber market linkage. The Muth-type EDM uses a less restrictive assumption that allows the possibility of substitution between factors of production (Alston, 1991). Specifically, we estimate the impacts on price and quantity changes and the resulted benefits or costs to (1) Russian log producers, (2) Russian lumber producers (the consumers of Russian logs), (3) Russian treasury, (4) foreign log buyers, and (5) foreign lumber buyers. The sum of (1) to (3) is the net benefits or costs to Russia, and that of (4) to (5) is the net benefits or costs to the rest-of-the-world (ROW). The sum of Russian and ROW benefits and costs gives the total world benefits or deadweight loss.

This study differs from other investigations of this question insofar as it is based on a Muth-type EDM, considering factor substitution in lumber production and feedback effects on log demand. Furthermore, we illustrate the log-lumber market interaction in a graphical analysis.

Finally, the primary parameters used in this chapter—the elasticities of supply and demand for Russian lumber and log—are directly estimated using recent data. As a result, this paper reaches a conclusion that is different from previous studies. The next section presents a graphical analysis of the impacts of Russian log export tax on domestic and overseas log and lumber markets, followed by a theoretical analysis. Sections 4 and 5 provide our elasticity estimates of Russian domestic and export markets for logs and lumber and estimates of the prices, quantities, and welfare effects associated with the tax. The final section concludes.

2. Graphical Analysis

Lumber production uses two factors: logs and processing services. A vertical log-lumber model differs from one stage analysis in that prices of lumber and processing inputs are endogenous and have feedback effects on log demand. Fig. 2.1 presents a simple depiction of how the log export tax works in a partial-equilibrium setting in all four related markets: Russian domestic log market, log export market, domestic lumber market, and lumber export market. The superscripts G and L indicate the variables or demand and supply curves for logs and lumber, respectively. The subscripts 0 and 1 indicate variable values under market clearing conditions before and after the implementation of Russian log export tax, respectively. We abstract from the fact that the rate of log export tax changed several times after 2007, although we consider it in our empirical estimations.

The intersection of the log export supply (ES_0^G) and demand (ED^G) curves gives the free market equilibrium price P_0^G on the log market, and the corresponding free market equilibrium price of lumber is P_0^L. With these prices Russia produces Q_0^G and Q_0^L units of logs and lumber, respectively, and exports E_0^G and E_0^L units to the ROW market. Without considering lumber and processing services markets, the ad valorem tax results in the left-shifted and counter-clock wisely rotated export supply curve of logs from ES_0^G to ES_1^G. For a tax rate of τ, the absolute vertical shifts in the excess supply curve is the distance between A and B, with $\text{AB} = \tau \cdot P_0^G$.

However, there are feedback effects on domestic demand curve for logs when prices of lumber and processing services are endogenous. A decrease in domestic log price shifts lumber supply to the right and reduces lumber price. A lower lumber price shifts domestic log demand curve to the left. However, this is an intermediate state since the decrease in domestic log price also changes the economic substitution between factor inputs, which in turn has another feedback effect on domestic log demand. Specifically, the sign of cross-price effect must be positive in a two-input case (Varian, 1992). However, the gross effect on domestic log demand curve has no determinate sign. By price transmission relation between input factor and retail product, the price of processing services decreases when logs and processing services are gross substitutes and increases when they are gross complements. In the former case, the domestic demand curve for logs shifts to the left due to lower prices of lumber and processing services. In the latter case, the shift direction for log demand is uncertain since a lower lumber price shifts it to the left while a higher price of processing services shifts it to the right.

Here in the graphical analysis, we focus on the circumstance when the gross effect is to shift domestic log demand curve to the left to be consistent with our parameter estimation in section 4. Abstracting from the temporal ordering of the stages of production, domestic log demand curve shifts from D_0^G to D_1^G, making the observed or actual domestic log demand curve as D_*^G. As Russian log export supply equals the difference between Russian log supply and domestic log demand, the original export supply curve (without tax), ES_0^G becomes ES_{0*}^G when prices of lumber and processing services are endogenous. With this log export tax, Russian log export supply curve shifts to ES_{1*}^G, and the vertical distance between the original and new curves

(CD) is equal to $\tau \cdot P_0^G$ as well. In the new equilibrium, the log prices received by domestic producers and foreign buyers are P^G and P_E^G, respectively. With lumber supply curve shifts to S_1^L, lumber price decreases from P_0^L to P_1^L, and lumber export increases from E_0^L to E_1^L.

Again, as shown in Fig. 2.1a, the "actual" domestic equilibrium demand curve for logs is D_*^G, which traces out the demand responses to price changes in the log market holding the prices of lumber and processing services endogenous and the gross effect shifting domestic log demand to the left. This demand curve is less elastic than the one in which only log market is considered. A less elastic domestic demand would result in a less elastic Russian log export supply from ES_0^G to ES_{0*}^G. Because the burden of the tax would fall more on the less elastic side, this means that Russian log producers bear more tax burden than under an exogenous lumber and processing services market setting of ES_0^G in Fig. 2.1b.

Under the ad valorem tax rate τ, the distance of vertical shift CD is identical to AB, even though the burden of tax varies. In other words, without considering the vertical marketing channel from logs to lumber and a left-shifted domestic log demand curve, one tends to overestimate the impact of log export tax on foreign buyers of Russian logs and to underestimate its impact on decreasing domestic log price and the resulted increases in lumber production and exports.

3. Methodology

3.1. Structural Model

Muth (1964) developed a partial equilibrium model of firms' identical production using two factor inputs to measure the effects of shifts in retail demand and input supply. It incorporates the interaction between vertical markets, which fits well to a log-lumber market analysis. Sun (2006) and Li and Zhang (2010) are probably the only ones that uses a three (two) processing stages Muth-type EDM to estimate the welfare effects of forest policy. They are applications in a closed economy setting. We relax the assumption to an open economy setting and allow for trade in one of the inputs (logs) and output (lumber) because Russia is a net exporter of both logs and lumber. As market distortions brought by an export tax on log exports extend to both processing services and lumber markets, we consider two products and three markets in this study.

Following the basic assumption of a Muth-type EDM, in a vertical log-lumber model, lumber producers use two input factors (logs and processing services) under constant returns to scale (CRS). The export demand for Russian logs and lumber are assumed to be separate. By imposing a log export tax, Russian government gains tax revenue and domestic lumber producers receive an indirect subsidy from the resulted lower domestic log prices.

With the above settings, our vertical log-lumber model in Russia is represented by (a) the lumber market in Equations 1 to 4, (b) the log market in Equations 5 to 9, and (c) demand and supply for processing services in Equations 10 and 11. In particular, Equation 5 shows the vertical linkage between logs and lumber, and Equations 2 and 6 represents Russian exports in lumber and logs, respectively. The log export tax is the wedge between domestic log price and export price, as shown in Equation 7. This is our basic model for estimating the change in prices and quantities of logs and lumber in both domestic and export markets that result from exogenous demand shifts caused by the log export tax.

$D^L = D(P^L)$ (Domestic demand for lumber) (1)

$D_E^L = D_E(P^L)$ (Export demand for lumber from Russia) (2)

$S^L = f(D^G, I)$ (CRS production function of lumber) (3)

$S^L = D^L + D_E^L$ (Lumber market clearing) (4)

$P^G = P^L \cdot f_{D^G}(D^G, I)$ (Inverse demand for logs in Russia) (5)

$D_E^G = D_E'(P_E^G)$ (Export demand for logs from Russia) (6)

$P_E^G = P^G(1+\tau)$ (Log export tax) (7)

$S^G = S^G(P^G)$ (Supply for log) (8)

$S^G = D^G + D_E^G$ (Log market clearing) (9)

$P^I = P^L \cdot f_I(D^G, I)$ (Inverse demand for processing services) (10)

$I = S^I(P^I)$ (Supply for processing services) (11)

where f_i $(i = D^G, I)$ in Equations 5 and 10 are the marginal physical products of logs and processing services, respectively (or the input demand functions for logs and processing services, respectively) holding output price constant.

This model contains one exogenous variable—the log export tax τ—and 11 endogenous variables. The endogenous variables are D^L (Russian demand for lumber), D_E^L (ROW demand for Russian lumber), S^L (Russian lumber supply), P^L (price of lumber), D^G (Russian demand for logs), D_E^G (ROW demand for Russian logs), S^G (Russian log supply), P^G (Russian domestic log price), P_E^G (export supply price of Russian logs), I (processing services in lumber production), and P^I (price of processing services in Russia).

We estimate the changes in endogenous prices and quantities by totally differentiating the equations above and converting them into elasticity form:

$$\widetilde{D}^L = \eta_R^L \tilde{P}^L \quad (1')$$

$$\widetilde{D}_E^L = \eta_E^L \tilde{P}^L \quad (2')$$

$$\tilde{S}^L = k_G \widetilde{D}^G + (1 - k_G)\tilde{I} \quad (3')$$

$$\tilde{S}^L = k_1 \widetilde{D}^L + (1 - k_1)\widetilde{D}_E^L \quad (4')$$

$$\tilde{P}^G = \tilde{P}^L - \frac{1-k_G}{\sigma}(\widetilde{D}^G - \tilde{I}) \quad (5')$$

$$\widetilde{D}_E^G = \eta_E^G \widetilde{P}_E^G \quad (6')$$

$$\widetilde{P}_E^G = \widetilde{P}^G + \tau \quad (7')$$

$$\widetilde{S}^G = \varepsilon^G \widetilde{P}^G \quad (8')$$

$$\widetilde{S}^G = k_2 \widetilde{D}^G + (1 - k_2) \widetilde{D}_E^G \quad (9')$$

$$\widetilde{P}^I = \widetilde{P}^L + \frac{k_G}{\sigma} (\widetilde{D}^G - \widetilde{I}) \quad (10')$$

$$\widetilde{I} = \varepsilon^I \widetilde{P}^I \quad (11')$$

Equations 1' to 11' are expressed in percentage changes. η_R^L (< 0) and η_E^L (< 0) are the own-price elasticities of demand for lumber of Russia and the ROW. σ (≥ 0) is the elasticity of substitution between the two input factors—logs and processing services. η_E^G (< 0) is the own-price elasticity of demand for log of the ROW. $k_1 = D^L/S^L$ and $k_2 = D^G/S^G$ are domestic demand shares of lumber and logs, respectively. $k_G = P^G D^G / P^L S^L$ is the input share of logs in lumber production. ε^G (> 0) and ε^I (> 0) are the own-price elasticities of supply for logs and processing services. The tax shift is in price direction. For example, $\tau = 0.01$ represents a one percent shift of export supply of Russian logs to the left. The endogenous changes in quantities and prices are functions of exogenous tax shifts and parameters. Here we focus on deriving the reduced form for log price changes induced by the export tax. For comparison purpose, we first treat the prices of lumber and processing services as exogenous, even though we focus on the case in which they are endogenous in our empirical study.

3.2. Reduced Form for Log Prices under Exogenous Prices of Lumber and Processing Services

When the prices of lumber and processing services are exogenous, the effect of a log export tax on log export price is derived from Equations 5' to 9' only. In other words, we drop Equations 1' to 4', 10', and 11', and treat $\widetilde{P}^L$ and $\widetilde{P}^I$ $(\widetilde{I})$ at constant level $\bar{P}^L$ and $\bar{P}^I$ $(\bar{I})$, respectively. Solve Equations 5', 8', and 9' simultaneously for the export supply equation for logs to yield

$$\widetilde{D}_E^G = \varepsilon_{exo}^G \tilde{P}^G - k\sigma\bar{P}^L - k\bar{I} \tag{12}$$

where $\varepsilon_{exo}^G = \frac{(1-k_G)\varepsilon^G + k_2\sigma}{(1-k_G)(1-k_2)} > 0$ is the export supply elasticity for logs and $k = \frac{k_2}{(1-k_G)(1-k_2)} > 0$. Deleting the last two terms and setting Equation 12 equal to 6' and using Equation 7', we have the quasi reduced-form equations of domestic and export prices of logs with respect to the export tax

$$\frac{\tilde{P}_E^G}{\tau} = \frac{\varepsilon_{exo}^G}{\varepsilon_{exo}^G - \eta_E^G} \tag{13}$$

$$\frac{\tilde{P}^G}{\tau} = \frac{\eta_E^G}{\varepsilon_{exo}^G - \eta_E^G} \tag{14}$$

Since $\varepsilon_{exo}^G > 0$ and $\eta_E^G < 0$, the tax is split between a rise in the export price and a fall in the domestic price for logs ($\frac{\tilde{P}_E^G}{\tau} + \left|\frac{\tilde{P}^G}{\tau}\right| = 1$). In general, foreign consumers bear less of the tax incidence (a lower value of $\frac{\tilde{P}_E^G}{\tau}$) and domestic producers bear more (a higher value of $\left|\frac{\tilde{P}^G}{\tau}\right|$) when export supply becomes less elastic (a smaller ε_{exo}^G) in relation to export demand.

3.3. Reduced Form for Log Prices under Endogenous Prices of Lumber and Processing Services

Keep P^L as temporarily exogenous and solve Equations 1', 3', and 4' simultaneously to yield the export supply curve for lumber

$$\widetilde{D}_E^L = \varepsilon_e^L \tilde{P}^L + \frac{k_G}{1-k_1}\widetilde{D}^G + \frac{1-k_G}{1-k_1}\tilde{I} \tag{15}$$

where $\varepsilon_e^L = -\frac{k_1\eta_R^L}{1-k_1} > 0$ is the export supply elasticity of lumber. Substituting Equations 2', 10', and 11' into Equation 15, we get the price transmission relation between processing services and lumber

$$\tilde{P}^I = \frac{\eta^L+\sigma}{\varepsilon^I+\sigma}\tilde{P}^L \tag{16}$$

where $\eta^L = k_1\eta_R^L + (1-k_1)\eta_E^L$ is the overall demand elasticity for lumber.

Substitute $\widetilde{D}^G - \tilde{I} = \frac{\sigma}{k_G}(\tilde{P}^I - \tilde{P}^L)$ from Equation 10' into 5', we have

$$\tilde{P}^L = k_G\tilde{P}^G + (1-k_G)\tilde{P}^I \tag{17}$$

Combining Equations 11', 12, 16, and 17, we get the reduced-form export supply equation for logs allowing the prices of lumber and processing services to adjust

$$\widetilde{D}_E^G = \varepsilon_{exo}^G\tilde{P}^G - k\delta\left(\sigma + \varepsilon^I\frac{\eta^L+\sigma}{\varepsilon^I+\sigma}\right)\tilde{P}^G \tag{18}$$

where $k > 0$ as defined in section 3.2 and $\delta = \frac{k_G(\varepsilon^I+\sigma)}{(k_G-1)\eta^L+k_G\sigma+\varepsilon^I} > 0$. Equation 18 indicates that the export supply elasticity for logs when the prices of lumber and processing services are endogenous is

$$\varepsilon_{end}^G = \varepsilon_{exo}^G + \Phi \tag{19}$$

where $\Phi = -k\delta\left(\sigma + \varepsilon^I\frac{\eta^L+\sigma}{\varepsilon^I+\sigma}\right)$. The reduced-form equations of log prices with respect to the tax when prices of lumber and processing services are endogenous are

$$\frac{\tilde{P}_E^{G\prime}}{\tau} = \frac{\varepsilon_{end}^G}{\varepsilon_{end}^G-\eta_E^G} = \frac{\varepsilon_{exo}^G+\Phi}{\varepsilon_{exo}^G-\eta_E^G+\Phi} \tag{13'}$$

$$\frac{\tilde{P}^{G\prime}}{\tau} = \frac{\eta_E^G}{\varepsilon_{end}^G-\eta_E^G} = \frac{\eta_E^G}{\varepsilon_{exo}^G-\eta_E^G+\Phi} \tag{14'}$$

Since the sign of term Φ is uncertain, the export supply curve may be more or less elastic compared to the one market analysis of logs. When $|\eta^L| < \sigma$, logs and processing services are gross substitutes,[1] and $\varepsilon_{end}^G < \varepsilon_{exo}^G$ ($\Phi < 0$) indicates that export supply becomes less elastic

[1] Fore reference, see Alston and Scobie (1983), Kinnucan et al. (2000), and Kinnucan and Zhang (2015).

when we consider the vertical link between logs and lumber markets. In this case, Russian log producers bear more of the tax burden. In other words, the negative effects of log export tax on the equilibrium price for log producers will be underestimated if we only consider the log market, which is to say that the absolute value of $\frac{\tilde{P}^{G\prime}}{\tau}$ in Equation 14' is greater than that of $\frac{\tilde{P}^{G}}{\tau}$ in Equation 14. However, when $|\eta^L| > \sigma$, logs and processing services are gross complements. In this case, we can only have $\varepsilon_{end}^G < \varepsilon_{exo}^G$ if $\sigma(\varepsilon^I + \sigma) > -\varepsilon^I(\eta^L + \sigma)$.

3.4. Welfare Calculations

Numerical solutions can be obtained by substituting the values of tax and parameters into Equations 1' through 11' and then solving for the percentage changes in prices and quantities. To measure welfare impacts, we assume that the supply and demand curves are linear in their relevant ranges. This linear assumption provides a good approximation regardless of the true functional forms of supply and demand curves (Alston et al., 1995). As Alston (1991) and Lusk and Anderson (2004) show, once the changes in equilibrium prices and quantities are obtained, the welfare distributions are measured as

$$\Delta CS^L = -P_0^L D_0^L \tilde{P}^L (1 + 0.5\tilde{D}^L) \tag{20}$$

$$\Delta PS^G = P_0^G S_0^G \tilde{P}^G (1 + 0.5\tilde{S}^G) \tag{21}$$

$$\Delta PS^I = P_0^I I_0 \tilde{P}^I (1 + 0.5\tilde{I}) \tag{22}$$

$$TR = P_{E0}^G D_{E0}^G \cdot \tau (1 + \tilde{D}_E^G) \tag{23}$$

$$\Delta CS_E^G = -P_{E0}^G D_{E0}^G \tilde{P}_E^G (1 + 0.5\tilde{D}_E^G) \tag{24}$$

$$\Delta CS_E^L = -P_0^L D_{E0}^L \tilde{P}^L (1 + 0.5\tilde{D}_E^L) \tag{25}$$

where ΔCS^L is the welfare change for Russian lumber consumers as indicated by area $P_0^L P_1^L NM$ in Fig. 2.1c, ΔPS^G is the welfare change for Russian log producers as measured in quasi-rents to logs of area $P_0^G P^G KJ$ in Fig. 2.1a, and ΔPS^I is the welfare change for Russian lumber producers as measured in quasi-rents to processing services.[2] Russian government receives tax revenue TR as indicated by area $P_E^G P^G DC$ in Fig. 2.1b. The sum of Equations 20 to 23 is the total welfare change to Russia. The welfare changes to foreign log and lumber buyers are ΔCS_E^G and ΔCS_E^L as indicated by areas $P_E^G P_0^G EC$ and $P_0^L P_1^L HF$ in Figs. 2.1b and 2.1d, respectively. The variables with subscript 0 take their values at the initial market equilibrium in the base year.

4. Parameters Estimation

Usually, the values of parameters in Equations 1' to 11' are taken from literature. As far as we know, there is no study measuring the demand and supply elasticities of Russian log and lumber.[3] Solberg et al. (2010) assume the price elasticity of log supply to be 1.5 in Russia and the price elasticity for end forest product demand to be -0.2 to -0.3 and use a global forest sector model to predict Russian and global forest product markets under different tax levels. This elasticity of log supply is much higher than that of the other regions measured in literature (e.g., Newman, 1987; Newman and Wear, 1993; Niquidet and Tang, 2013).

In this study, we estimate the elasticities using time series models of the domestic and export markets for Russian logs and lumber. The demand or supply quantity Q_t is a function of price P_t and a vector of lagged quantity Q_{t-i}, which is specified as

$$\ln Q_t = \alpha + \beta \cdot \ln P_t + \vartheta \cdot \ln Q_{t-i} + \varepsilon_t \tag{26}$$

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[2] These equations measuring producer surplus changes are valid since there are no shifts in both factor supply curves. For the case of pivotal shifts in factor supply, see Chung and Kaiser (1999).

[3] The Global Forest Products Model uses demand elasticities of end products (like coniferous lumber) for major countries without considering product source. It does not have demand elasticity for logs since logs are factor inputs. In our paper, coniferous logs are inputs as well as an intermediate product for exports. Therefore, we estimate domestic and export demand elasticities separately in following analysis.

To estimate the prices and quantities impacts through Equations 1' to 11' and welfare effects through Equations 20 to 25, we need to estimate six parameters

η_R^L (Russia demand elasticity for lumber),

η_E^L (export demand elasticity for lumber from Russia),

η_E^G (export demand elasticity for logs from Russia),

ε^G (Russia logs supply elasticity),

ε^I (processing services supply elasticity), and

σ (substitution elasticity between log and processing services).

These parameters are β in Equation 26, which we estimate based on their corresponding quantity and price values. Since we introduce the lag $\ln Q_{t-i}$ of the dependent variable as an exogenous variable in the partial adjustments model in Equation 26, $\ln Q_t$ and $\ln P_t$ should be first-difference stationary and the residual ε_t is white noise. The presence of serial correlation is an evidence of model misspecification, which may be corrected by including additional lags of the dependent variable (Pickup, 2014). However, there may be estimation biases of β from two sources. One is that price may be endogenous since we omitted control variables. The other problem is simultaneous equation bias. To control for these biases, we first instrument the price variable with its lag value and the other variables in Equations 1 to 11. Then the final instruments in 2SLS regression are selected following a general-to-specific methodology to avoid over-identification.

We have 23 years of data from 1992 to 2014. Data on Russian production, consumption, and exports in logs and lumber are from FAO (2016). Price is defined as the ratio of total value to total quantity as a common practice in trade studies (Shiells, 1991; Luo et al., 2015). The value of processing services is determined as the annual difference between the value of processed lumber and cost of logs. We use inflation-adjusted per capita GDP in Russia as the price of processing services and derive the quantity of processing services by dividing its value with the price.[4] As shown in Table 2.2, all variables are first-difference stationary based on Augmented Dickey–Fuller and Phillips–Perron unit root tests (Phillips and Perron, 1988; Becketti, 2013).

The OLS and 2SLS estimation results of Equation 26 are presented in Table 2.3. Durbin and Wu-Hausman tests cannot reject the exogeneity hypothesis for the potentially endogenous price variable at the 10% level for all estimations. Therefore, we confine our results to the OLS estimation. Residual correlation is checked by ARCH LM test and Durbin's H-test. The null hypothesis of no serial correlation cannot be rejected at the 5% significant level with one lag except for the estimation of processing services supply function ($\ln I$). We add a second lag of dependent variable $\ln I_{t-2}$ to control for possible serial correlation in this equation.

The foreign lumber buyers (elasticity = -0.32) are more responsive to lumber price compared to Russian domestic consumers (elasticity = -0.21). The excess demand elasticity for Russian logs is around -0.41. China is the largest importer both of Russian logs and lumber. Sun (2014) estimates the Marshallian demand elasticity of -0.41 for China's demand for coniferous roundwood from Russia, which is similar to the value we get here. Russian log supply is inelastic with an elasticity of 0.12, although it is insignificant at the 10% level.

Factor substitution elasticity is estimated based on Equation 5'. The empirical model is

$$\ln(P_t^G / P_t^L) = a + \gamma \ln(D_t^G / I_t) + e_t \qquad (27)$$

[4] There is no estimate on the supply elasticity for processing services in literature. Here we use the per capita GDP as the price for processing services because labor cost is the second largest component of lumber manufacturing cost.

The dependent and independent variables are all level stationary (Table 2.2). The estimated value for γ is -1.66 (S.E.=0.42). The input share of logs in lumber production was 0.65 in 2006. With $-\frac{1-k_G}{\sigma}=\gamma$, we get an approximate value for factor substitution elasticity σ of 0.21. Stier (1980) estimates the elasticity of substitution in lumber processing of 0.27 in the United States, which is similar to what we get for Russia. These elasticity estimates and other parameters in Table 2.1 are used as the baseline values for our deterministic simulations.

Besides deterministic simulations, we present stochastic simulations on the marginal effects of a 1% ad valorem export tax on prices and quantities. In the stochastic simulations, the parameters in Table 2.1 are treated as random variables following a normal distribution. The standard errors of k_G, k_1, and k_2 are calculated assuming that the lower and upper bounds of their 95% confidences intervals are 0.8 and 1.2 times their respective baseline values. The real standard error of ε^G is assumed to be half of its estimated value. Mean values and confidence limits of marginal effects are computed using *Simetar*, a spreadsheet add-in in *Excel*.

5. Welfare Estimation

Table 2.4 presents the results of our simulations. While the results from our deterministic simulations are strictly from the application of Equations 1’ to 11’, those of stochastic simulations are generated by using 1,000 random draws with coefficients and standard errors listed in Table 2.1. In general, all the mean values of the marginal effects of a 1% log export tax are similar in both deterministic and simulation estimations. In the following analysis, we use the results of the stochastic simulations.

5.1. Prices and Quantities

We estimate the market impacts under two (2006 and 2012) scenarios. Using 2006 as the baseline scenario, we find that the burden of the log export tax is nearly equally distributed between Russian log producers and foreign log buyers.[5] Specifically, each 1% increase in log export tax increases the equilibrium log export price by 0.52% and reduces the equilibrium price in domestic market by 0.48%. As indicated in Fig. 2.1b, the share of log export tax burden does not change with the tax rate, as it is determined by the relative values of log excess supply and excess demand elasticities. Thus, when the log export tax is 25%, equilibrium domestic log price drops by 12%, and equilibrium log export price increases by 13%.

The fall in Russian log price does promote its domestic lumber production, as expected. The equilibrium quantity of domestic log demand in lumber production goes up by 0.14% under a 1% log export tax. Both lumber producers and consumers benefit from decreases in domestic log price. Each 1% increase in the tax reduces equilibrium lumber price by 0.28%. Moreover, at the equilibrium level, domestic and export demand for Russian lumber increase by 0.06% and 0.12%, respectively.

Even though equilibrium quantity of domestic log demand increases, the equilibrium quantity of Russian log supply decreases with the log export tax. Each 1% log export tax decreases equilibrium log supply by 0.04%, but this effect is not significantly different from 0 at the 5% level as reflected by its 95% confidence interval (shown in Table 2.4). Overall, with an isolated 1% increase in log export tax, the equilibrium demand for, and the price of, processing services increase by 0.02% and 0.09%, respectively.

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[5] The nearly equally distributed tax burden suggests that the elasticities of export supply and export demand for logs are approximately equal in absolute value. Using parameter values in Table 2.1 and Equation 19, we have the export supply elasticity $\varepsilon_{end}^{G} = 0.50$. With $\eta_{E}^{G} = 0.41$, we get $\frac{\tilde{P}_E^G}{\tau} = 0.55$ and $\frac{\tilde{P}^G}{\tau} = -0.45$ according to Equations 13’ and 14’, which are the same results as the determinate simulation of 2006 scenario in Table 2.4.

Note that the simulated results are sensitive to the parameter k_2, domestic demand share of logs. This is apparent under the 2012 scenario. In 2012, 77% of Russian logs was consumed domestically. In the last three columns of Table 2.4, we present the marginal effects of 1% log export tax when k_1=0.35 and k_2=0.77. A 1% log export tax increases equilibrium lumber supply by 5%, which is much lower than the 10% level under the 2006 scenario. In other words, the effectiveness of a log export tax on promoting domestic lumber production decreases with domestic demand share of logs. Compared to the 0.48% decrease under the 2006 scenario, the equilibrium price of logs in domestic market goes down only by 0.23% when there is 1% log export tax in 2012, which in turn has a smaller impact on domestic lumber production.

5.2. Welfare Distribution

The welfare effects calculated with the mean values of stochastic simulations are reported in Table 2.5. Since the tax rate varied between 2007 and 2012, we calculate the welfare changes in each period based on the tax rate. Overall, the equilibrium domestic price of and total demand for Russian logs decrease with the imposition of the log export tax. Therefore, Russian log producers suffered. The percentage change in welfare increases with the rate of the ad valorem export tax. Total welfare loss to Russian log producers was US $2.85 billion between January 2007 and June 2012, which was a 21% decrease compared to the 2006 level. Meanwhile, total welfare loss to ROW log buyers was US $1.63 billion, which was 23% of its initial equilibrium welfare level in 2006.

On the other hand, Russian lumber producers and consumers benefited from the log export tax. Specifically, domestic lumber consumers gained more than domestic lumber producers (US $0.4 billion vs. US $0.14 billion). As about two-thirds of Russian lumber were exported, foreign lumber buyers benefited about twice (US $0.8 billion) as much as Russian domestic lumber consumers. Together, foreign buyers of Russian logs and lumber lost US $0.8 billion.

Finally, Russian government gained tax revenue of US $3.04 billion, which was big enough to cover the welfare loss to its log producers. In aggregate, Russia benefited from the log export tax, with a net gain of US $0.74 billion between January 2007 and June 2012.

In sum, with the log export tax, Russia was able to benefit at the expense of foreign log buyers. Domestically, there was also a welfare transfer from log producers to lumber producers, lumber consumers, and Russian treasury. Foreign buyers as a whole lost for Russia's national interest. The total deadweight loss was about US $79 million, which increases with the export tax rate.

6. Conclusions

In this paper, we develop a vertical log-lumber market model to estimate the effects of Russian log export tax. Our model covers two products and three markets. We specify the demand for Russian logs to be constrained by lumber production and the ROW buyers and estimate, for the first time, several parameters for Russian log and lumber markets. Using these parameters, we find that the incidence of Russian log export tax on log prices is nearly equally distributed between Russian log producers and foreign log buyers, with foreign log buyers bearing 52% of the tax burden. While Russian logging sector suffered from the log export tax, the country benefited with a welfare gain of US $742 million between January 2007 and July 2012. This means that the loss in its logging sector is transferred to domestic lumber producers, domestic lumber consumers, and Russian treasury. Foreign buyers of Russian lumber gained about twice that of domestic lumber consumers, although the benefits to foreign lumber buyers are not sufficient to compensate for the losses of foreign log buyers in the study period.

From a national perspective, Russia succeeded by imposing an export tax on softwood logs between 2007 and 2012, owing to its dominant position as a log exporter and ability to discriminate against foreign log buyers. By imposing the log export tax, Russia also reduced output in its domestic logging sector, which might have brought some environmental benefits to the country, and promoted the development of its domestic lumber industry. In contrast, the export tax clearly harmed foreign consumers of Russia's exported logs and generated a deadweight loss in the wood products market as a whole. As Russia entered the World Trade Organization in 2012, it had to rescind its log export tax and use more non-tax barriers to limit its log exports instead. Compared to an export tax, an export quota is clearly a second choice as it harms Russian logging sector with no tax offset to the Russian treasury, but Russian logging sector benefits from less loss in its quasi-rents. Further studies could focus on the employment impacts and conservation benefits associated with the Russian log export tax, the price, welfare and employment impacts of Russian log export quota since 2013, and the feasibility of promoting Russian lumber in global markets.

Table 2.1 Parameters and baseline values for Russian lumber and logs sectors

Item	Definition	Value	S.E.
η_R^L	Domestic demand elasticity for lumber	-0.21	0.09
η_E^L	Export demand elasticity for lumber from Russia	-0.32	0.12
η_E^G	Export demand elasticity for logs from Russia	-0.41	0.11
ε^G	Domestic logs supply elasticity	0.12	0.10
ε^I	Domestic processing services supply elasticity	0.40	0.10
σ	Factor substitution elasticity	0.21	0.02
k_G	Input share of logs in lumber production	0.65	0.07
k_1	Domestic demand share of lumber	0.34	0.03
k_2	Domestic demand share of logs	0.47	0.05
$P_0^L D_0^L$	Value of domestic lumber demand (2005 US $ billion)	1.18	na
$P_0^G S_0^G$	Value of supplied logs (2005 US $ billion)	4.75	na
$P_0^I I_0$	Value of processing services (2005 US $ billion)	1.20	na
D_{E0}^G	Export demand quantity for logs from Russia (million m^3)	36.40	na
P_{E0}^G	Export demand price for logs from Russia (2005 US $/$m^3$)	69.37	na
$P_0^L D_{E0}^L$	Value of export demand for lumber from Russia (2005 US $ billion)	2.25	na
$P_{E0}^G D_{E0}^G$	Value of export demand for logs from Russia (2005 US $ billion)	2.53	na

Note: Elasticity parameters are estimated using annual data from 1992 to 2014. Baseline values are in 2006, the year before the implementation of Russian log export tax.

Table 2.2 Stationarity analysis of variables

	ADF		PERRON	
	level	1st differenced	level	1st differenced
$\ln D^L$	-2.46	-5.49***	-2.48	-5.40***
$\ln P^L$	-2.38	-10.32***	-2.39	-8.93***
$\ln D_E^L$	0.04	-4.10***	-0.10	-4.17***
$\ln D_E^G$	-2.16	-6.07***	-2.14	-5.66***
$\ln P_E^G$	-0.87	-4.51***	-1.03	-4.47***
$\ln S^G$	-2.54	-15.04***	-2.53	-11.69***
$\ln P^G$	-1.65	-4.83***	-1.80	-4.73***
$\ln I$	-1.96	-7.78***	-1.87	-6.86***
$\ln P^I$	0.38	-2.72*	-0.08	-2.62
$\ln(P^G / P^L)$	-15.73***	na	-15.03***	na
$\ln(D^G / I)$	-4.96***	na	-4.87***	na

Table 2.3 Estimation results of parameters

	$\ln D^L$		$\ln D^L_E$		$\ln D^G_E$		$\ln S^G$		$\ln I$	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
$\ln P$	-0.21**	-0.19*	-0.32**	-0.51***	-0.41***	-0.41***	0.12	0.32	0.40***	0.39***
	(0.09)	(0.10)	(0.12)	(0.16)	(0.11)	(0.13)	(0.20)	(0.27)	(0.10)	(0.10)
$\ln Q_{t-1}$	-0.71***	0.71***	1.10***	1.15***	0.82***	0.82***	0.49	0.42	0.28*	0.29**
	(0.10)	(0.09)	(0.07)	(0.08)	(0.09)	(0.08)	(0.30)	(0.32)	(0.14)	(0.13)
$\ln Q_{t-2}$	na	na	na	na	na	na	na	na	0.38**	0.38***
									(0.14)	(0.13)
Constant	5.80***	5.65***	0.07	0.21	4.73**	4.73***	8.55*	9.00*	0.66	0.78
	(1.76)	(1.42)	(0.83)	(0.87)	(1.70)	(1.63)	(4.69)	(4.63)	(1.54)	(1.39)
R^2	0.75	0.75	0.96	0.96	0.85	0.85	0.30	0.29	0.77	0.77
ARCH	0.51		0.12		0.68		3.76*		0.03	
H-test[a]	0.02		0.00		3.61*		0.45		5.08**	
R^2 (1st stage)		0.94		0.77		0.86		0.87		0.98
Durbin[b]		0.78		1.96		0.00		1.43		1.02
Wu-Hausman		0.81		2.29		0.00		1.76		0.82
Overi-dentify		9.18		4.28				6.05		

Note: *** P<0.01; ** P<0.05; * P<0.10. The standard errors (S.E.) are in the parentheses under each coefficient. ARCH is the LM test for autoregressive conditional heteroscedasticity with the null hypothesis of no ARCH effects. H-test[a] is Durbin's H-test for autocorrelation with the null hypothesis of no serial correlation. Durbin[b] is the Durbin test of endogeneity for the 2SLS estimation.

Table 2.4 Marginal effects of 1% log export tax on the percentage changes in prices and quantities

	Baseline=2006 (k_1=0.34, k_2=0.47)			Baseline=2012 (k_1=0.35, k_2=0.77)		
	Deterministic Simulation	Stochastic Simulation		Deterministic Simulation	Stochastic Simulation	
		Mean	95% CI		Mean	95% CI
$\tilde{P}^G$	-0.45	-0.48	(-0.72, -0.28)	-0.21	-0.23	(-0.38, -0.13)
$\tilde{P}_E^G$	0.55	0.52	(0.28, 0.72)	0.79	0.77	(0.62, 0.87)
$\tilde{D}^G$	0.14	0.14	(0.06, 0.23)	0.06	0.07	(0.03, 0.12)
$\tilde{D}_E^G$	-0.22	-0.21	(-0.31, -0.10)	-0.32	-0.31	(-0.44, -0.18)
$\tilde{S}^G$	-0.05	-0.04	(-0.10, 0.03)	-0.02	-0.02	(-0.05, 0.02)
$\tilde{P}^L$	-0.34	-0.28	(-0.44, -0.17)	-0.16	-0.14	(-0.22, -0.08)
$\tilde{D}^L$	0.07	0.06	(0.02, 0.11)	0.03	0.03	(0.01, 0.05)
$\tilde{D}_E^L$	0.11	0.12	(0.05, 0.21)	0.05	0.06	(0.02, 0.11)
$\tilde{S}^L$	0.10	0.10	(0.04, 0.16)	0.04	0.05	(0.02, 0.08)
$\tilde{P}^I$	0.04	0.09	(-0.01, 0.21)	0.02	0.04	(-0.01, 0.11)
$\tilde{I}$	0.02	0.02	(-0.00, 0.04)	0.01	0.01	(-0.00, 0.02)

Note: Confidence intervals (CI) listed use 1000 random draws.

Table 2.5 Welfare effects based on stochastic simulations (baseline=2006)

	τ = 0.065		τ = 0.20		τ = 0.25		Total	
	%	US $ million	%	US $ million	%	US $ million	%	US $ million
Period	Jan 1, 07 - June 30, 07		July 1, 07 - Mar 31, 08		Apr 1, 08 - July 30, 12		Jan 1, 07 - June 30, 12	
Welfare distribution for Russia								
ΔCS^L	3.65	10.77	11.29	49.91	14.13	360.95	12.81	421.62
ΔPS^G	-6.19	-73.53	-18.98	-338.36	-23.70	-2440.99	-21.49	-2852.88
ΔPS^I	1.16	3.48	3.57	16.08	4.47	116.18	4.05	135.74
TR		80.96		363.05		2593.62		3037.63
Sum		21.68		90.67		629.76		742.11
Welfare distribution for foreign consumers								
ΔCS_E^G	-6.76	-42.67	-20.50	-194.15	-25.49	-1394.76	-23.15	-1631.57
ΔCS_E^L	3.66	20.60	11.35	95.82	14.23	694.06	12.90	810.49
Sum		-22.07		-98.32		-700.69		-821.08
Deadweight loss		-0.39		-7.65		-70.93		-78.97

Note: Percentage changes of welfare are compared to their initial equilibrium values in 2006. The welfare changes in foreign market only account for Russian exports to the international market and do not cover the rest-of-the-world domestic log and lumber markets.

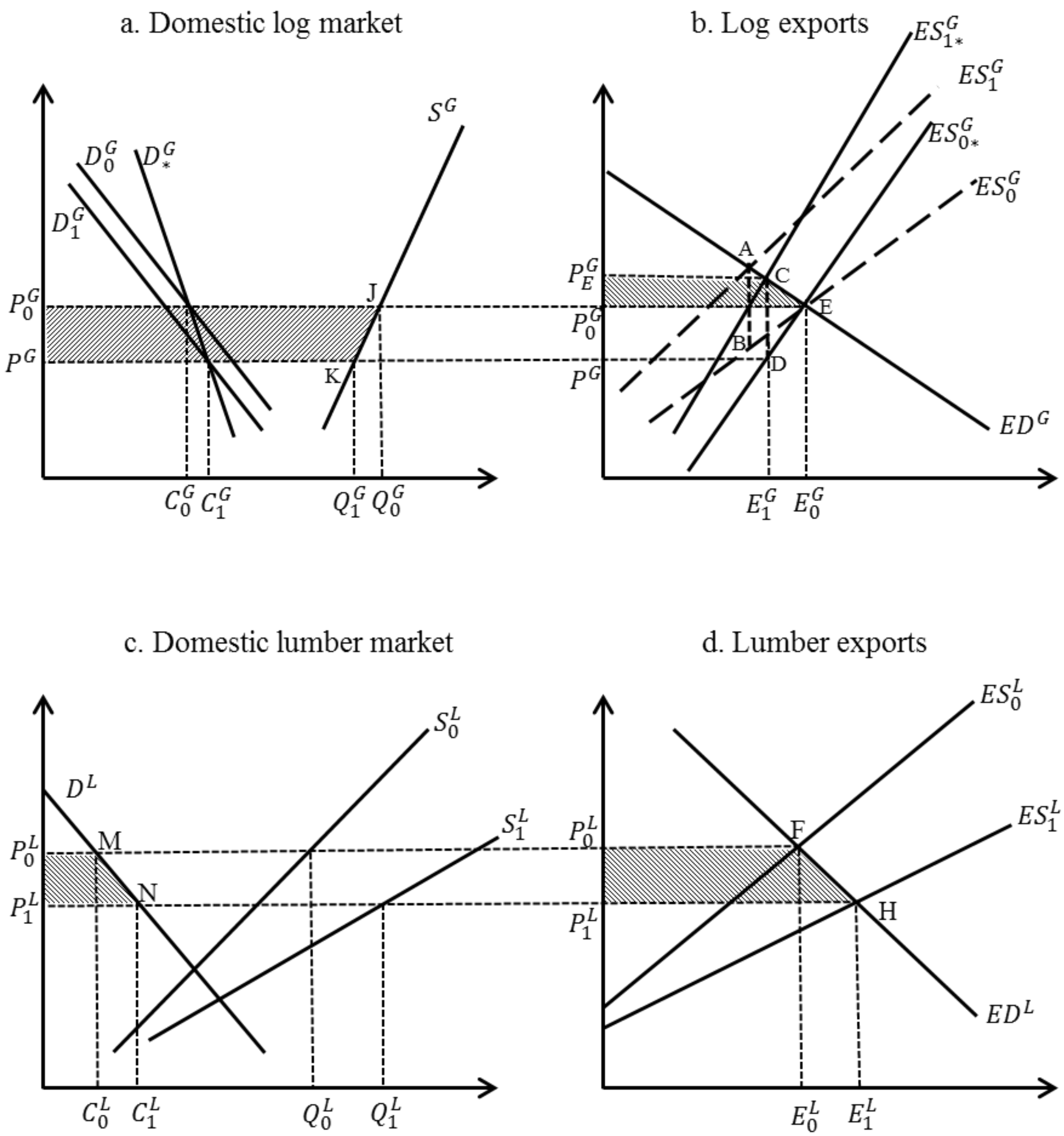


Fig. 2.1 The effects of Russian log export tax: Vertical log-lumber markets

Chapter 3. The Impacts of EU Timber Regulation: Market Diversion and Product Substitution

Abstract

The EU Timber Regulation (EUTR) adopted in October 2010 and enforced in March 2013 prohibits the import or placement of illegal timber on the EU market. In this paper, we use quarterly trade data to quantify the impacts of EUTR on import quantities by EU member state and by product. Our results show that most north and central European countries significantly decreased their imports of tropical and temperate timber products. Furthermore, the United Kingdom and some southeast and south-central European countries significantly decreased their imports of tropical timber products and increased their imports of temperate plywood. Finally, significant increases in the imports of tropical logs have been observed in western and north-central European countries.

Keywords: Illegal logging, international trade, timber products, EU Timber Regulation

1. Introduction

The trade of illegally logged timber products has detrimental effects on forestry, undermines legal trade, and threatens environmental sustainability. In addition to supporting forest certification and sustainable forest management, some developed countries have tried to use trade regulations to curb illegal logging in recent years. In October 2010, the European Commission adopted the EU Timber Regulation (EUTR, Regulation No. 995/2010), as a key element of the EU Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan, to act as part of its endeavors to tackle illegal logging from the demand (import) side of forest product trade. The EUTR requires operators placing timber products on the EU market to exercise due diligence and traders in import countries to keep records of their suppliers and customers. The EUTR came into full effect in March 2013.

A recent evaluation report by the EU described market diversion and product substitution before and after the EUTR (European Commission, 2016). However, there is no quantitative study on the impacts of EUTR on international timber trade. The challenge is that, besides the intervention of trade regulation, timber imports are influenced by macroeconomic factors such as purchasing power, exchange rate movements, and construction activity. In this paper, we try to quantify the effects of EUTR using econometric models.

Although the EUTR is an innovative law covering all countries in the EU, there are differences in implementation and enforcement among states since the EUTR was carried out within national context (European Commission, 2016). As such, operators may import timber to member states with lax regulations. Exporters, on the other hand, will possibly divert timber to destinations with less stringent regulatory frameworks (Jonsson et al., 2015). Therefore, we hypothesize that the effects of EUTR were different across states, with smaller impacts likely for states with less stringent implementation rules and larger impacts for countries with strict enforcement of the EUTR.

In general, the EUTR is expected to reduce—at least in the short run—the imports of tropical timber products from sources containing high rates of illegal logging. At the same time, economic principles suggest that temperate timber products may fill in the resulting gap in supply (Jonsson et al., 2015). Some evaluation reports describe possible substitution of temperate timber and alternative materials for tropical hardwoods in major importing markets (Goetzl and Ekström, 2007; Villazón, 2009). There are processing companies in the EU member states that have historically used tropical timber confirmed their shift to temperate timber as it makes for easier compliance with the EUTR (European Commission, 2016).

The objective of this study is to quantify the effects of EUTR on the import demand of timber by EU member state and by product. Specifically, we estimate the impacts of EUTR on the quantities of six timber products imported into each member state, i.e., tropical logs (wood in the rough), temperate logs (wood in the rough), tropical lumber, temperate lumber, tropical plywood, and temperate plywood. In this way, we can detect the possible substitution of temperate timber for tropical timber on the national level, and the possible diversion of tropical timber to destinations with a relatively laxer regulatory framework within the EU markets. Multivariate regression models of individual time series are used to isolate the confounding influences of other macroeconomic factors. The two-step approach by Engle and Granger (1987) are employed with quarterly time series data to evaluate cointegration and long-run equilibrium relationships, with error correction models detecting transitory effects of the EUTR.

This study provides a benchmark assessment for policymakers to better understand the effectiveness of EUTR on reducing illegal timber imports, or its effects on the trade of tropical products where illegal logging and other violations of forestry and timber related laws are suspected to be extensive. Additionally, it reveals a process of adjustment undertaken by operators in light of possible trend changes in international timber trade markets. Since the impact of EUTR is estimated at the national level, this study provides some evidence on the differences in implementation process across EU member states, possibly contributing to policy improvements aimed at harmonizing the enforcement of EUTR.

2. Methods

This paper adopts a two-region non-spatial partial equilibrium model, between a member state and the rest of the world (ROW). The Marshallian demand function is specified as

$$Q_{ijt} = f(P_{ijt}, Y_{jt}) \quad (1)$$

where Q_{ijt} is the imported quantity of timber product i by country j in time t. P_{ijt} is the real import price of product i by country j in time t. Y_{jt} is the real domestic income of country j in time t.

Studies have found statistically significant permanent or transitory effects of exchange rate on the trade of forest products, both for exports (Sun and Zhang, 2003; Bolkesjø and Buongiorno, 2006) and imports (Prestemon, 2015; Zhang et al., 2017). An appreciation in domestic currency decreases the price of foreign timber products in domestic markets and encourages imports. Besides, the issuance of EUTR coincided with a global economic and financial crisis that significantly dampened wood-based housing construction activities in the EU markets. These factors should have impacts on the import demand for timber products in the EU.

To accommodate the possible influences of exchange rate and construction activities, we augment Equation 1 and write it in logarithmic form

$$\ln Q_{ijt} = \alpha_0 + \alpha_1 \ln P_{ijt} + \alpha_2 \ln Y_{jt} + \alpha_3 \ln E_{jt} + \alpha_4 \ln C_{jt} + \alpha_5 R_{1t} + \alpha_6 R_{2t} + \alpha_q T + \varepsilon_{ijt} \quad (2)$$

where P_{ijt}, Y_{jt}, E_{jt}, and C_{jt} are real (inflation adjusted) import price, domestic income, exchange rate, and value-added gross construction, and T is a vector of dummies controlling seasonality. We specify the shock of EUTR as two dummy variables, that is R_{1t} equal to 0 before its adoption

(2010Q4) and 1 thereafter and R_{2t} equal to 0 before its coming into force (2013Q1) and 1 thereafter. The reason is that the EUTR created the framework for tacking illegal logging from the demand side while member states hold different levels of preparation and implementation since its adoption.

As noted earlier, we have six products ($i = 6$) for each member state j in Equation 2. Table 3.1 shows how product categories are assembled from quarterly data from the database of European Commission (Eurostat, 2016). The data are 69 consecutive quarters from 1999Q1 to 2016Q1. Tropical plywood is defined as plywood with at least one outer layer of tropical wood. The import quantity and value of temperate plywood subtract these of coniferous plywood (HTS codes 4412.19 and 4412.39 for periods during 1999-2006 and 2007-2016, respectively) and tropical plywood from total plywood (HTS code 4412) in each quarter. We caution that the temperate plywood has at least one outer layer of temperate wood while it may contain plywood with at least one layer of tropical wood. The dataset reports quantities in 100 KG and values in euros. We define the price of a product group, i.e., unit value, as the ratio of total value to total quantity as a common practice in trade studies (Shiells, 1991; Luo et al., 2015). As the value data of imported timber products are reported in nominal values, we convert them to their real counterparts in 2010 base year using national level GDP deflator available at the European Commission (Eurostat, 2016). Our quarterly GDP and value-added gross construction data are from the European Commission (Eurostat, 2016), in constant 2010 million euros. Real exchange rate data are obtained from the Federal Reserve Board of St. Louis (2016) for each member state, which is calculated as the weighted averages of bilateral exchange rates adjusted by relative consumer prices.

The empirical estimation of Equation 2 starts with a test for stationarity of each variable in the model. Nonstationary data may result in spurious regression and inconsistent parameters unless the time series variables are integrated in the same order and cointegrated (Granger and Newbold, 1974; Enders, 2004; Hill et al., 2011). We test the unit root properties using the Dickey-Fuller generalized least squares (DF-GLS) test because of its greater statistical power in small samples (Elliott et al., 1996). The specification of the DF-GLS test is with drift only and the number of lags is selected according to Schwartz information criterion. Since for the import models of each EU member state, we test the stationarity of import quantity, import price, GDP, real exchange rate, and construction, the results are not listed in this paper to save space. Most of the time series are first-differenced stationary according to the DF-GLS test while the remaining are first-differenced stationary using Phillips–Perron unit-root test (Phillips and Perron, 1988).

Since the series are I(1) integrated, we test the long run Engle-Granger cointegration relations of the import model, i.e. Equation 2, based on the two-step approach (Engle and Granger, 1987). The test results reject the null hypothesis for the import demand models of each member state, and we conclude that there are long-run cointegration relations in each import model. The existence of cointegration suggests that the time series in Equation 2 are tied together and that the error correction model (ECM) can be estimated to detect the adjustment of import quantity difference ($\Delta \ln Q_{ijt}$) toward the dynamic equilibrium. Here, we estimate a first order ECM which includes the lag of the residual series ε_{ijt} along with stationary first-differences of time series

$$\Delta \ln Q_{ijt} = \beta_0 + \beta_1 \Delta \ln P_{ijt} + \beta_2 \Delta \ln Y_{jt} + \beta_3 \Delta \ln E_{jt} + \beta_4 \Delta \ln C_{jt} + \beta_5 \Delta R_{1t} + \beta_6 \Delta R_{2t} + \beta_s \varepsilon_{ijt-1} + \beta_q T + \delta_{ijt} \quad (3)$$

where δ_{ijt} are white noise residuals. The coefficients β_i $(i = 1 - 6)$ in Equation 3 show the transitional adjustment in $\ln Q_{ijt}$ with respect to each exogenous variable, assuming the model is in a dynamic equilibrium. As all variables are in logarithmic values, β_i are the arc estimates of the transitory elasticities independent of adjustment relative to the dynamic equilibrium. β_s is the speed of adjustment towards long-run equilibrium, and a significant negative β_s is an evidence that the time series variables are cointegrated. The adjustment in an exogenous variable towards the dynamic equilibrium equals $-\beta_s\alpha_i$, where α_i $(\mathrm{i} = 1 - 6)$ is its long run elasticity estimated in Equation 2. Therefore, the short-run effect of an exogenous variable after one quarter is

$$\gamma_i = \beta_i - \beta_s\alpha_i \tag{4}$$

which is the sum of a transitory effect and a scaled adjustment effect. If the transitory effect is statistically insignificant, the short-run effect is $-\beta_s\alpha_i$. Here in this paper, we focus on the effects of EUTR, which are γ_5 and γ_6, indicating the level increases in import quantities due to the adoption and enforcement of EUTR, respectively.

There is a common error that the coefficient of a dummy variable, multiplied by 100, is equal to the percentage effect of that variable on the endogenous variable being explained in logarithmic regression equations. Following Halvorsen and Palmquist (1980) and Kennedy (1981), the change in import quantities due to the EUTR is

$$\rho_i = \exp\left(e_i - \frac{1}{2}var(e_i)\right) - 1 \tag{5}$$

where e_i can correspond to the long run effects α_i $(i = 5, 6)$ in Equation 2 and the short-run effects γ_i $(i = 5, 6)$ in Equation 4, and $var(e_i)$ is the variance of e_i. The variance of γ_i $(i = 5, 6)$ is calculated by error propagation in this paper.

Both the static and dynamic models in Eqs. 2 and 3 can be estimated by seemingly unrelated regression (SUR). Time series are cointegrated as evidenced by Engle-Granger tests, and the estimated coefficients of the error correction term β_s are significantly negative at the 5% level in each estimation of Equation3.[6] Residuals in Equation 3 are checked for autocorrelation by Durbin-Waston test and homoscedasticity by ARCH test. All these results ensure that the estimated coefficients in Eqs. 2 and 3 are unbiased and consistent.

[6] Detailed results of all the mentioned estimates are available from the authors.

3. The Case of United Kingdom

The UK is among the EU's biggest tropical timber importers and also an important market in international timber trade. In 2010, about 18.8 million KG of tropical timber products, or 12% of the EU imports, were imported into the UK.[7] Even before the EUTR was introduced, UK had had a strong record of tackling illegal logging and its associated trade (Jonsson et al., 2015) and was ranked first in the WWF Government Barometer (2014) assessing EU member's efforts to tackle illegal logging. With growing consumer awareness and enforcement action, its total tropical timber imports dropped to 11.3 million KG, and the corresponding percentage of EU imports decreased to 5% in 2015. Considering its vital role in the EU and international timber markets, the UK is selected as the representative of our estimating process and results.

Fig. 3.1 depicts UK's timber import quantities by product. There was a continuous decrease in import quantity of tropical logs from 2012Q2 to 2014Q4. And there were seasonal fluctuations in temperate logs imports. Table 3.2 presents the unit root test results of individual time series of the UK. We have 15 variables for the UK, which are the logarithm values of the import quantities and import prices of the six timber products, GDP, exchange rate, and gross construction. All the time series variables of UK are first-differenced stationary at the 1% significance level according to the DF-GLS unit root tests except the import quantity of tropical lumber, import price of tropical lumber, and GDP. These three series are indeed difference stationary according to Phillips-Perron tests at the 1% significance level.

Engle-Granger two-step approach confirms the cointegration relationship in each of the six import models at the 1% significance level (Table 3.3). In the long-run cointegration, import price had significant negative effects on import quantity except that of temperate plywood. Given the

[7] The EU imports are the sum of all 28 member states.

magnitudes of price elasticities from 1 to 1.5, it is clear that import quantities responded elastically to import price changes. Moreover, the imports of tropical logs and lumber were less elastic than those of temperate logs and lumber. Among the six products, only temperate plywood imports responded significantly to GDP changes. The income elasticity of temperate plywood imports was around 1.1, indicating that a higher proportion of income was spent on temperate plywood imports as the income of UK consumers increased. The real exchange rate had significant positive effects on the imports of tropical logs, tropical and temperate lumber, and temperate plywood. Therefore, the euro appreciation had positive and significant effects on imports with elasticities between 0.7 (of temperate plywood) to 1.9 (of tropical logs).

The adoption of EUTR had statistically significant and negative effects on the imports of temperate logs and tropical plywood but statistically positive effects on these of temperate lumber and temperate plywood in the long-run cointegration. Moreover, the enforcement of EUTR had statistically significant and negative effects on the imports of tropical logs and tropical lumber. Overall, the EUTR had significant negative effects on the imports of both tropical and temperate logs, and the UK importers could have substituted temperate lumber and plywood for tropical lumber and plywood.

Table 3.4 presents the estimation results of error correction model in Equation 3. The error correction term had statistically significant and negative effects on the first-differenced import quantities of all the timber products, which implies that the time series variables were cointegrated. The Durbin-Waston test values were around 2 in all the estimations, indicating that there were no autocorrelations. The Engle LM ARCH tests indicate that there were no heteroscedasticity in all the error correction models of the UK's imports. The import of temperate logs had the highest speed of adjustment, and it took about one-quarter (=1/1.04) adjusting towards long-run equilibrium. The adjustment of tropical lumber had the lowest speed of about two quarters (=1/0.57). We also calculate the short-run effects using the coefficients isolating the transitional adjustments, which are reported with the estimation results of other states in the next section.

4. Estimated Effects of the EUTR for Other States

As for UK, we estimate import demand equations of different products in an SUR for each state. Import demand for tropical logs was dropped from estimation for several states (Estonia, Hungary, Lithuania, Latvia, Romania, Cyprus, and Finland) since there are zero values in import quantities which resulting in less than 50 consecutive quarters during 1999Q1 to 2016Q1. Moreover, we did not estimate Malta since there are limited consecutive observations on its import quantities of both tropical and temperate logs. To save space, we limit results reported in Tables 3.5-7 to the effects of EUTR on import quantities. Though several products are estimated for a member state, we do not report here the effects of EUTR when they are insignificant at the 10% level for both the long-run and short-run estimations. Short-run effects of the EUTR are not calculated when the long-run effects and transitory effects are both insignificant at the 10% level.

Except that the EUTR did not have significant effects on the timber imports of Lithuania, the remaining 26 states can be summarized into three main groups based on the effects of EUTR. For estimations when the adoption and enforcement of EUTR had significant but opposite effects on one certain timber product, we use the additive value as the total effect when summarizing the state into one of the following three groups: (i) states reduced their imports of both tropical and temperate timber products (thereafter referred to as *negative effects group*); (ii) states substituted temperate timber for tropical timber, indicating decreasing imports of tropical timber products while increasing imports of at least one category of temperate timber products (*substituting effects group*);

(iii) states increased their imports of at least one category of tropical timber products (*positive effects group*).

4.1 Negative Effects Group

About 38% of the states recorded statistically significant decreases in import quantities of both tropical and temperate timber products due to the EUTR. These states include Denmark, Finland, Germany, Belgium, Sweden, Estonia, Slovenia, Latvia, Bulgaria, and Slovakia, which are north and central European countries (Fig. 3.3). Typically, in this group, most of the short-run effects were smaller than long-run effects in magnitude.

The largest change of tropical log imports occurred in Slovenia, where the adoption of EUTR decreased its imports by 60% after one-quarter and expanded to 89% in the long run. The imports of tropical logs by Denmark, Germany, and Sweden decreased significantly due to the adoption (47 to 62%) and enforcement (38 to 55%) of EUTR in the long run. While the tropical log imports of Belgium did not respond to the adoption of EUTR, it decreased by about 16% after one-quarter and 29% in the long run since the coming into force of EUTR. In the long run, there were no significant positive effects of the EUTR on temperate logs imports for states in this negative effects group. But in the short run, Germany, Sweden, Slovenia, and Slovakia significantly increased their imports of temperate logs. This result is possible because these states increased their imports of temperate logs in the short run faced with shortage of legal tropical log supply.

All states in this group exhibited negative responses in the imports of tropical and temperate lumber to the EUTR. The reason for this result could be that the supply sources of both tropical and temperate lumber for countries in this group contained considerable amounts of illegal lumber before the EUTR. The largest two quantity changes of tropical lumber were for Finland and Sweden which decreased approximately 95% and 96% in the long-run equilibrium. The decreases in temperate lumber imports were much smaller, with total effects of 54% and 32% for Finland and Sweden, respectively. One noteworthy finding is that the adoption of the EUTR (in 2010) had significant and positive effects on Slovakia's tropical and temperate lumber imports while its enforcement (in 2013) had significant but negative effects, both in the long run and short run.

The largest quantity change of tropical plywood occurred in Bulgaria, where the adoption of EUTR decreased tropical plywood imports by 74% both in the long run and short run. The marginal effects of EUTR on temperate plywood imports were mostly smaller than its effects on tropical plywood imports. For example, the adoption of EUTR decreased Denmark's temperate plywood imports by 33%, which was smaller than its effects on tropical plywood imports (-55%).

4.2 Substituting Effects Group

About 23% of the states decreased their imports of tropical timber products while increased imports of at least one category of temperate timber products, providing evidence that the EUTR might have caused product substitution in some EU member states. These states are the UK, Cyprus, Romania, Austria, Greece, and Hungary, which are mainly southeast and south-central European countries with the exception of UK (Fig. 3.3). Though its influencing directions on temperate logs or lumber varied among states, the EUTR had significant and positive effects on the imports of temperate plywood for all these states.

The largest quantity change in tropical log imports occurred in Austria, where the adoption of EUTR decreased its imports by 88% in the long run and 86% in the short run. Austria increased its temperate log imports in the same period, with larger marginal effects of 135% in the long run and 693% after the first quarter of the EUTR shock. Two states, the UK and Greece decreased their imports of both tropical and temperate logs. In the long run, the enforcement of EUTR had a significant 67% negative effect on the UK's imports of tropical logs and its enforcement decreased temperate log imports significantly by 83%. For Greece, the negative effects of EUTR's adoption were insignificant, but its enforcement decreased the imports of both tropical and temperate logs significantly in the long run and short run.

The UK and Cyprus decreased their tropical lumber imports significantly and increased temperate lumber imports significantly, both in the long run and short run. On the other hand, Romania, Austria, Greece, and Hungary decreased their imports in both lumber products. The largest quantity change of lumber was for Cyprus, where the enforcement of EUTR decreased tropical lumber imports by 60% and increased temperate lumber imports by 153%.

The UK, Romania, and Hungary decreased their imports of tropical plywood and increased these of temperate plywood significantly. For Cyprus and Austria, though the effects of EUTR on the imports of tropical plywood were insignificant at the 10% level, they increased imports of temperate plywood significantly, with marginal effects between 70% and 80% in the long run. Interestingly, Greece decreased its imports of tropical plywood by 51% due to the adoption of EUTR while increased tropical plywood imports with a larger magnitude of 80% since its enforcement.

4.3 Positive Effects Group

The remaining 38% of EU member states increased their imports in at least one category of tropical timber products. These states are Portugal, Netherlands, France, Luxembourg, Czech Republic, Croatia, Ireland, Italy, Poland, and Spain, which are mainly western and north-central European countries (Fig. 3.3). The influencing directions of the EUTR were inconsistent on tropical lumber and plywood imports among states. However, all of the states in this positive effects group had increased their imports in tropical logs significantly in the long run or short run since the implementation of the EUTR.

To illustrate, we use Poland and Spain as an example of this group. The EUTR had significant and positive effects on the imports of all tropical and temperate timber products in these two countries. The largest quantity changes were on tropical logs for both states. The adoption of EUTR increased tropical log imports by 188% and 265% for Poland and Spain after the first quarter, and the effects then moderated to 65% and 161% respectively in the long run. Poland and Spain had the lowest scores on their performances of curbing illegal logging as assessed and reported in WWF Government Barometer (2014). Another example is Irelands and Netherlands. The percentage increase in tropical log imports was higher in Irelands than Netherlands. Also, Ireland's efforts in curbing illegal logging were much lower compared to that of Netherlands (WWF Government Barometer, 2014). These results show that the EUTR was implemented unevenly between states and that the illegal timber products may enter the EU markets through states with less stringent regulations after the EUTR.

Except for Netherlands, all other states in this group increased their imports in temperate plywood significantly. The largest quantity change record of temperate plywood was for Portugal, where the enforcement of EUTR increased its imports by 20% in the short run and expanded to 50% in the long run equilibrium.

5. Conclusions and discussion

The trade of illegal timber products has caused widespread concerns among governments, non-governmental organizations, trade associations, and landowners. Illegal logging would crowd out legal products, decrease market prices, and cause environmental problems. In recent decades, the support of legality verification began to give a new focus to the demand side, as some of the world's leading economies committed series of trade regulations. In this study, we use econometric models to quantify the effects of the EU Timber Regulation on timber product imports of the EU member states. We find that there are geographical variations in member states' responses of timber product imports to the EUTR. The results may be complementary to various survey-based reports on the effects of EUTR.

States with higher performance and more stringent enforcement of the EUTR would be more likely to reduce their imports of timber products and consume more timber from domestic forests. The WWF Government Barometer (2014) assessed each EU member's efforts to tackle illegal logging with an overall score ranging from 0 (lowest efforts) to 16 (highest efforts). Fig. 3.2 presents the three groups' efforts to tackle illegal logging and percentage changes of forest area from 2010 to 2015, where efforts are averaged WWF scores over all states in each group and forest area includes the area of both natural and planted forests. The negative effects group has the highest average score of 6.1 on the performance of curbing illegal logging, while it is 3.8 for the positive effects group. As expected, the substitute effects group has a moderate score of 5.3. There are also within group differences as indicated by states' heterogeneous responses in tropical timber imports in the positive effects group. Moreover, the negative effects group has the lowest increase rate (0.18%) in forest area from 2010 to 2015 (Fig. 3.2). These results provide evidence that states implemented the EUTR unevenly and that states with higher performance on curbing illegal logging had higher possibilities to decrease their imports. Moreover, those states may turn to the domestic market for timber supply.

Although we pointed out the uneven implementation of the EUTR and possible market diversion between states, remaining issue meriting additional research is regarding to what extent the suppliers in sourcing countries now divert the illegal production towards their own domestic markets and whether they now export more legal timber to destinations with high regulations. As Prestemon (2015) states, both trade diversion and domestic consumption shifts are a form of policy “leakage”. Moreover, legality verification regimes are complex and evolving dynamically at both global and country level. The judgment should be withheld and updated with a dynamic perspective.

Table 3.1 Product groups and Harmonized Tariff System (HTS) codes

Product	HTS codes (1996-2006)	HTS codes (2007-)
Tropical logs (in the rough)	4403.41, 4403.49	4403.41 to 4403.49
Temperate logs (in the rough)	4403.99	4403.99
Tropical lumber	4407.24 to 4407.29	4407.21 to 4407.29
Temperate lumber	4407.99	4407.99
Tropical plywood	4412.13	4412.31
Temperate plywood	4412 minus 4412.13 and 4412.19[a]	4412 minus 4412.31 and 4412.39[b]

Note: [a, b] Plywood with both outer layers of coniferous wood.

Table 3.2 Results of the unit root tests of individual time series of United Kingdom

	DF-GLS test				Phillips-Perron test	
	Levels		1st Differenced		1st Differenced	
	Lags	DF-GLS	Lags	DF-GLS	Lags	Z(t)
Quantity_tropical logs	2	-0.41	1	-7.78***		
Quantity_temperate logs	6	-1.72	2	-8.76***		
Quantity_tropical lumber	1	-0.02	3	-0.93	3	-14.68***
Quantity_temperate lumber	1	-1.43	1	-5.59***		
Quantity_tropical plywood	1	-2.70***	2	-2.78***		
Quantity_temperate plywood	1	-2.35**	1	-5.16***		
Price_tropical logs	1	-2.82***	2	-7.60***		
Price_temperate logs	1	-2.19*	1	-7.10***		
Price_tropical lumber	1	-0.89	3	-1.02	3	-11.59***
Price_temperate lumber	1	-1.62	1	-6.02***		
Price_tropical plywood	1	-2.00*	1	-5.56***		
Price_temperate plywood	1	-3.55***	3	-6.48***		
GDP	5	0.46	3	-1.06	3	-10.05***
Exchange rate	1	-0.94	1	-4.31***		
Construction	5	-0.88	4	-3.52***		

Note: All level data are in their natural logarithm values. *** P<0.01, ** P<0.05, * P<0.10.

Table 3.3 Estimation results of long-run cointegration of United Kingdom's imports by product

	ln (import quantity)					
	Tropical logs	Temperate logs	Tropical lumber	Temperate lumber	Tropical plywood	Temperate plywood
ln (price)	-1.03***	-1.48***	-0.99***	-1.24***	-1.23***	-0.13
	0.15	0.28	0.19	0.05	0.21	0.22
ln (GDP)	-0.59	2.32	-0.30	-0.79	0.92	1.13***
	1.60	3.68	0.60	0.49	0.88	0.46
ln (exchange rate)	1.86**	-0.94	0.80***	1.66***	-0.16	0.67***
	0.84	1.84	0.29	0.26	0.47	0.26
ln (construction)	-0.68	-2.50	-0.10	0.29	-0.30	0.42
	1.33	3.05	0.50	0.42	0.76	0.40
$EUTR_{10}$	-0.22	-1.69***	-0.08	0.14***	-0.37***	0.15***
	0.17	0.46	0.06	0.05	0.10	0.05
$EUTR_{13}$	-1.09***	-0.26	-0.16**	-0.05	0.12	-0.08
	0.18	0.40	0.06	0.05	0.10	0.05
$Quarter_2$	0.00	-0.29	-0.07	0.10*	0.01	0.09***
	0.12	0.27	0.04	0.04	0.07	0.04
$Quarter_3$	-0.22*	-0.25	0.02	0.03	0.04	0.10***
	0.12	0.27	0.04	0.04	0.07	0.04
$Quarter_4$	-0.10	-0.18	-0.04	-0.05	0.03	-0.02
	0.13	0.28	0.04	0.04	0.07	0.04
Constant	20.47	17.44	17.94***	17.02***	9.20	-7.90**
	13.64	30.77	4.74	4.11	7.53	4.65
R^2	0.85	0.41	0.83	0.96	0.63	0.59
Dickey-Fuller test	-5.98***	-9.16***	-4.73***	-6.59***	-6.43***	-6.75***

Note: Engle-Granger cointegration is tested by Dickey-Fuller regression. The 1%, 5%, and 10% critical values for Dickey-Fuller test are -2.61, -1.95, and -1.61. *** P<0.01, ** P<0.05, * P<0.10.

Table 3.4 Estimation results of error correction model of United Kingdom's imports by product

	Δln (import quantity)					
	Tropical logs	Temperate logs	Tropical lumber	Temperate lumber	Tropical plywood	Temperate plywood
ECM	-0.71***	-1.04***	-0.57***	-0.81***	-0.81***	-0.72***
	0.11	0.11	0.09	0.10	0.12	0.13
Δln(price)	-1.15***	-1.62***	-1.41***	-1.09***	-1.10***	-0.34*
	0.12	0.25	0.21	0.08	0.22	0.20
Δln(GDP)	-0.26	10.92	2.18	-0.82	1.55	1.06
	4.69	10.58	1.48	1.45	2.79	1.51
Δln(exchange rate)	-1.99	-1.99	-0.59	0.89	-0.76	0.56
	1.83	4.48	0.60	0.58	1.18	0.63
Δln(construction)	-0.30	-8.26	0.98	0.78	1.14	0.27
	2.06	4.75	0.67	0.66	1.27	0.68
$\Delta EUTR_{10}$	0.04	0.40	-0.06	0.21**	-0.35*	0.02
	0.33	0.76	0.11	0.11	0.20	0.11
$\Delta EUTR_{13}$	-0.41	0.98	-0.12	-0.03	-0.06	0.03
	0.33	0.75	0.11	0.11	0.20	0.11
$Quarter_2$	0.02	-0.47	-0.06	0.06	0.07	0.09**
	0.13	0.29	0.04	0.04	0.08	0.04
$Quarter_3$	-0.11	-0.28	-0.03	-0.12*	0.01	0.01
	0.20	0.45	0.06	0.06	0.12	0.06
$Quarter_4$	0.12	-0.41	-0.18***	-0.13**	-0.02	-0.10*
	0.18	0.43	0.06	0.06	0.11	0.06
Constant	-0.04	0.22	0.05	0.05	-0.02	0.00
	0.10	0.23	0.03	0.03	0.06	0.03
R^2	0.72	0.68	0.63	0.75	0.62	0.55
Durbin-Watson test	2.11	1.93	1.89	1.89	1.97	1.79
ARCH test	1.69	2.56	0.18	0.60	0.64	0.11

Note: The P-values of the Engle LM ARCH test are greater than 0.10 for all the error correction models of United Kingdom's imports. *** P<0.01, ** P<0.05, * P<0.10.

Table 3.5 Estimated effects of EUTR on import quantities for states in negative effects group

	Long-run				Short-run			
	α_5	Elas.	α_6	Elas.	γ_5	Elas.	γ_6	Elas.
Denmark 11								
Tropical logs	-0.60**	-0.47	-0.45*	-0.38	-1.36***	-0.77	-0.26*	-0.24
Temperate logs	0.22	0.17	0.06	0.01			1.17*	1.51
Tropical lumber	-0.55	-0.42	-0.36***	-0.30	0.28*	0.30	0.19*	0.20
Temperate lumber	-0.13	-0.13	-0.25***	-0.22			-0.07**	-0.07
Tropical plywood	-0.78***	-0.55	-0.06	-0.07	-1.32***	-0.74		
Temperate plywood	-0.39***	-0.33	-0.11	-0.11	-0.06**	-0.06		
Finland 9								
Tropical lumber	-0.68***	-0.50	-0.58***	-0.45	-0.93***	-0.62	-0.98***	-0.64
Temperate lumber	-0.35***	-0.30	-0.27**	-0.24	-0.11**	-0.10	-0.08**	-0.08
Tropical plywood	-0.54**	-0.44	0.24	0.24	-0.36**	-0.32		
Temperate plywood	-0.08	-0.08	-0.28***	-0.25			-0.11**	-0.10
Germany 9								
Tropical logs	-0.93***	-0.62	-0.78***	-0.55	-0.42***	-0.35	-0.35***	-0.30
Temperate logs	0.58	0.63	0.10	0.05	1.80***	4.10	1.77***	3.92
Tropical lumber	-0.27***	-0.24	-0.08	-0.08	-0.09**	-0.09		
Temperate lumber	-0.26***	-0.23	-0.16**	-0.15	-0.08***	-0.07	-0.19**	-0.17
Tropical plywood	-0.28***	-0.25	-0.15*	-0.14	-0.14**	-0.13	-0.08*	-0.07
Temperate plywood	-0.03	-0.03	-0.15**	-0.07			-0.06*	-0.05
Belgium 8								
Tropical logs	-0.17	-0.16	-0.33**	-0.29			-0.17**	-0.16
Temperate lumber	-0.24***	-0.22	-0.07	-0.07	-0.08**	-0.07		
Temperate plywood	-0.32***	-0.28	0.07	0.07	-0.11***	-0.11		
Sweden 7								
Tropical logs	-0.89***	-0.61	-0.69**	-0.52	-1.83***	-0.87	-2.15***	-0.90
Temperate logs	0.36	0.33	0.17	0.14	1.57***	3.12	1.18**	1.79
Tropical lumber	-0.83***	-0.57	-0.49***	-0.39	-0.38***	-0.32	-0.82***	-0.58
Temperate lumber	-0.32*	-0.28	-0.13	-0.13	-0.09*	-0.09		
Tropical plywood	-0.03	-0.05	-0.68***	-0.50			-0.27***	-0.24
Estonia 7								
Temperate logs	-0.24	-0.25	-0.70*	-0.54			-0.67*	-0.52
Temperate lumber	-0.11	-0.11	-0.14	-0.13	-0.30**	-0.26	-0.28**	-0.25
Slovenia 7								
Tropical logs	-1.97***	-0.89	-0.30	-0.34	-0.86**	-0.60		
Temperate logs	0.28	0.21	0.05	0.00	1.41***	2.60	1.20**	1.90
Tropical lumber	-0.34	-0.31	0.26	0.27			0.55*	0.65
Temperate lumber	-0.30**	-0.27	-0.10	-0.10	-0.08**	-0.08		

Tropical plywood	-0.73***	-0.53	-0.09	-0.09	-0.23***	-0.21		
Temperate plywood	-0.20*	-0.19	0.15*	0.16	-0.07*	-0.07	0.05*	0.05
Latvia 4								
Temperate logs	-0.67	-0.55	0.37	0.35	1.02*	1.35	1.42**	2.44
Tropical lumber	0.14	0.06	-0.60*	-0.48			-0.44*	-0.38
Temperate lumber	-0.15	-0.15	-0.20	-0.19			-0.83***	-0.58
Tropical plywood	1.21	1.37	-0.03	-0.23	-2.34*	-0.96		
Temperate plywood	0.48***	0.59	-0.57***	-0.44	0.58***	0.75	-0.66***	-0.49
Bulgaria 3								
Temperate logs	-1.20***	-0.73	0.48	0.51	-1.35***	-0.77		
Tropical lumber	-1.06***	-0.67	-0.17	-0.18	-0.70***	-0.52		
Temperate lumber	-0.98***	-0.65	-0.05	-0.09	-0.24**	-0.22		
Tropical plywood	-1.23***	-0.74	-0.50	-0.45	-1.23**	-0.74		
Temperate plywood	-0.53**	-0.43	-0.32	-0.29	-0.15*	-0.14		
Slovakia 1								
Temperate logs	-0.12	-0.16	-0.43	-0.39	1.90***	4.56		
Tropical lumber	0.48**	0.58	-0.58**	-0.46	0.49**	0.58	-0.58**	-0.46
Temperate lumber	1.49***	3.34	-1.78***	-0.84	0.70***	0.96	-2.16***	-0.90
Tropical plywood	-0.29	-0.31	-1.35***	-0.76			-1.24***	-0.73
Temperate plywood	-0.39***	-0.32	0.17**	0.18	-0.20***	-0.18	0.09**	0.09

Note: *** P<0.01, ** P<0.05, * P<0.10. α_5 and α_6 are the estimated long run effects of the adoption and enforcement of EUTR, and γ_5 and γ_6 are the corresponding short run effects. Elas. stands for the percentage effect of EUTR on import quantities. The number following state name is its score on efforts to tackle illegal logging reported in the WWF Government Barometer (2014) ranging from 0 (lowest efforts) to 16 (highest efforts).

Table 3.6 Estimated effects of EUTR on import quantities for states in substituting effects group

	Long-run				Short-run			
	α_5	Elas.	α_6	Elas.	γ_5	Elas.	γ_6	Elas.
United Kingdom 14								
Tropical logs	-0.22	-0.21	-1.09***	-0.67			-0.78***	-0.55
Temperate logs	-1.69***	-0.83	-0.26	-0.29	-1.76***	-0.85		
Tropical lumber	-0.08	-0.08	-0.16**	-0.15			-0.09**	-0.09
Temperate lumber	0.14***	0.15	-0.05	-0.05	0.32***	0.37		
Tropical plywood	-0.37***	-0.31	0.12	0.13	-0.65***	-0.49		
Temperate plywood	0.15***	0.16	-0.08	-0.08	0.11***	0.11		
Cyprus 7								
Tropical lumber	-0.18	-0.19	-0.85***	-0.60			-0.84**	-0.59
Temperate lumber	-0.39	-0.37	1.08**	1.53			2.03**	4.35
Tropical plywood	-0.21	-0.20	-0.03	-0.07	-0.60**	-0.47		
Temperate plywood	-0.28	-0.26	0.65*	0.80			1.22**	1.99
Romania 5								
Temperate logs	0.21	0.12	-0.28	-0.32	2.05**	4.08		
Tropical lumber	-0.77***	-0.54	-0.51***	-0.41	-0.89***	-0.61	-0.29***	-0.25
Temperate lumber	-0.62***	-0.47	0.03	0.02	-0.40***	-0.33		
Tropical plywood	-0.97***	-0.63	-0.50*	-0.41	-0.85***	-0.58	-0.44*	-0.37
Temperate plywood	0.28***	0.31	0.12	0.12	0.21***	0.23		
Austria 4								
Tropical logs	-1.92***	-0.88	0.90	0.75	-1.77***	-0.86		
Temperate logs	0.93**	1.35	-0.18	-0.27	2.41***	6.93		
Tropical lumber	-0.32**	-0.28	0.14	0.12	-0.22**	-0.21		
Temperate lumber	-0.05	-0.06	-0.26***	-0.23			-0.09*	-0.09
Temperate plywood	0.54***	0.71	-0.08	-0.08	0.18***	0.19		
Greece 2								
Tropical logs	-0.78	-0.60	-1.46***	-0.79			-7.29***	-1.00
Temperate logs	-0.52	-0.49	-1.67***	-0.83			-2.25***	-0.92
Tropical lumber	-0.49***	-0.40	0.35**	0.40	-0.36**	-0.31	0.25**	0.28
Temperate lumber	-0.83***	-0.57	0.11	0.10	-0.34***	-0.29		
Tropical plywood	-0.70***	-0.51	0.60***	0.80	-0.95***	-0.63	0.37***	0.44
Temperate plywood	0.68***	0.96	0.67***	0.93	0.34***	0.40	0.33***	0.39
Hungary 0								
Temperate logs	0.54*	0.63	0.24	0.19	2.22***	6.11	1.65**	3.21
Tropical lumber	-0.33	-0.30	-0.85***	-0.58			-0.56***	-0.44
Tropical plywood	0.08	0.04	-0.54*	-0.44			-0.17*	-0.16
Temperate plywood	-0.02	-0.02	0.25***	0.28			0.13***	0.14

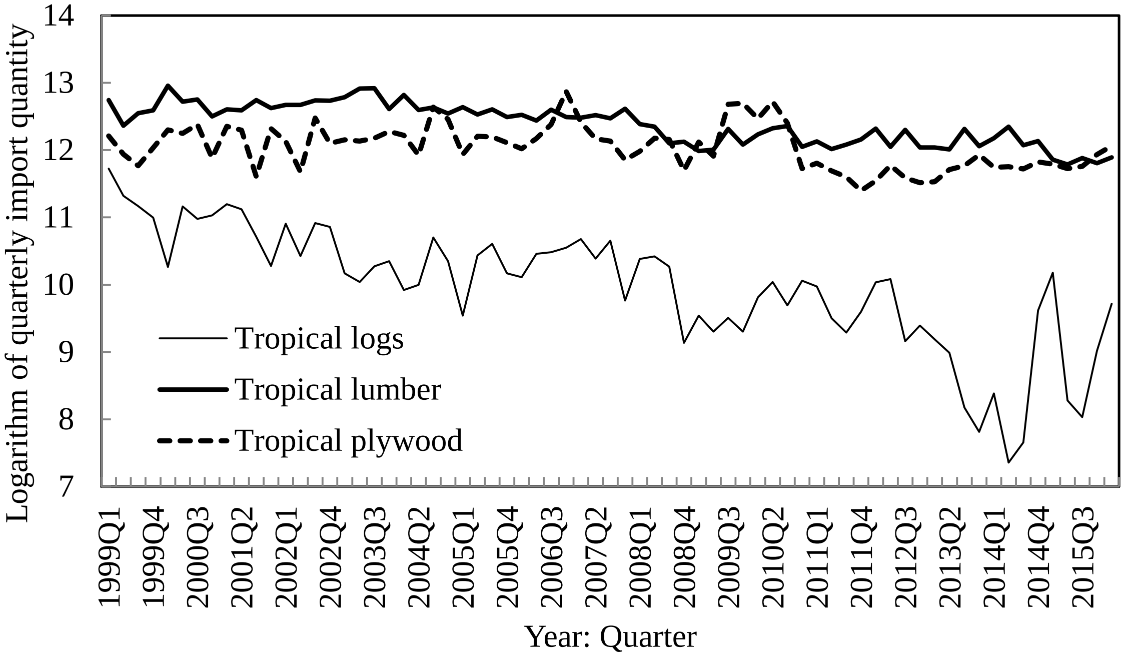
Note: *** P<0.01, ** P<0.05, * P<0.10. α_5 and α_6 are the estimated long run effects of the adoption and enforcement of EUTR, and γ_5 and γ_6 are the corresponding short run effects. Elas. stands for the percentage effect of EUTR on import quantities. The number following state name is its score on efforts to tackle illegal logging reported in the WWF Government Barometer (2014) ranging from 0 (lowest efforts) to 16 (highest efforts).

Table 3.7 Estimated effects of EUTR on import quantities for states in positive effects group

	Long-run				Short-run			
	α_5	Elas.	α_6	Elas.	γ_5	Elas.	γ_6	Elas.
Portugal 8								
Tropical logs	0.07	0.06	0.38**	0.44			0.26**	0.28
Temperate logs	0.58	0.61	0.41	0.40			1.12*	1.52
Temperate lumber	-0.09	-0.10	0.13	0.14	-0.28*	-0.26		
Temperate plywood	-0.11	-0.11	0.42***	0.50			0.18***	0.20
Netherlands 7								
Tropical logs	0.70**	0.91	0.38*	0.43	1.57***	3.36	0.88**	1.18
Tropical lumber	-0.37***	-0.31	-0.16**	-0.15	-0.12***	-0.11	-0.05**	-0.05
Temperate lumber	-0.28*	-0.25	-0.34**	-0.29	-0.09	-0.09	-0.11**	-0.10
Tropical plywood	-0.26***	-0.23	-0.03	-0.03	-0.35***	-0.30		
Temperate plywood	-0.05	-0.05	-0.16**	-0.15			-0.07**	-0.07
France 6								
Temperate logs	0.70	0.75	0.35	0.32	1.52**	2.72	1.18*	1.61
Temperate lumber	0.20*	0.21	0.34***	0.40	0.07*	0.08	0.13***	0.14
Tropical plywood	0.00	-0.01	-0.04	-0.05	0.21*	0.23		
Temperate plywood	-0.08	-0.07	0.15***	0.16			0.10***	0.10
Luxembourg 5								
Tropical logs	2.97***	10.72	0.32	0.27	3.29***	11.51		
Tropical lumber	0.74**	1.00	0.10	0.09	0.54**	0.67		
Tropical plywood	-1.42***	-0.76	-0.49***	-0.39	-1.34***	-0.75	-1.16***	-0.69
Temperate plywood	0.23	0.24	0.15	0.15			0.67***	0.91
Czech Republic 4								
Tropical logs	0.96**	1.34	-0.02	-0.14	0.69**	0.88	1.88*	2.89
Tropical lumber	-0.04	-0.05	-0.37**	-0.32			-0.15*	-0.14
Temperate lumber	-0.18**	-0.17	-0.35***	-0.30	-0.06**	-0.06	-0.11***	-0.10
Temperate plywood	0.03	0.02	0.13***	0.14			0.12***	0.12
Croatia 4								
Temperate logs	-0.81	-0.67	0.98*	1.25			0.75*	0.90
Tropical lumber	0.48*	0.56	0.01	-0.01	0.34*	0.38		
Temperate lumber	-0.27**	-0.25	0.02	0.02	-0.17**	-0.16		
Temperate plywood	-0.15	-0.15	0.18**	0.19	-0.25*	-0.23	0.13**	0.13
Ireland 2								
Tropical logs	0.80**	1.10	1.05***	1.76	0.41**	0.48	1.33***	2.47
Temperate logs	-0.15	-0.29	-1.31***	-0.75	1.86**	3.57	-1.36***	-0.77
Tropical lumber	0.54***	0.68	-0.31**	-0.27	1.09***	1.84	-0.21	-0.20
Temperate lumber	0.36**	0.42	-0.19*	-0.18	0.29**	0.33	-0.15	-0.14
Temperate plywood	0.35*	0.38	-0.09	-0.10	0.26*	0.28	0.44	0.50
Italy 1								

Tropical logs	-0.13	-0.16	0.09	0.06	0.54^{***}	0.68		
Temperate logs	0.40	0.26	0.05	-0.04			1.28^{*}	1.81
Tropical lumber	-0.34^{*}	-0.30	0.43^{***}	0.52	-0.05^{*}	-0.05	0.07^{**}	0.07
Temperate lumber	-0.27^{*}	-0.25	0.00	-0.01	-0.04^{*}	-0.04		
Tropical plywood	-0.31^{*}	-0.28	0.40^{***}	0.48	-0.16^{*}	-0.15	0.20^{***}	0.22
Temperate plywood	0.08	0.08	0.37^{***}	0.44			0.34^{***}	0.40
Poland 1								
Tropical logs	0.54^{**}	0.65	0.14	0.13	1.16^{**}	1.88		
Temperate logs	0.47	0.48	0.00	-0.05	1.27^{**}	1.99	1.29^{**}	2.02
Tropical lumber	0.12^{*}	0.12	-0.04	-0.04	0.11^{*}	0.11		
Tropical plywood	0.52^{***}	0.67	-0.01	-0.01	0.69^{***}	0.98	-0.36^{**}	-0.31
Temperate plywood	0.31^{***}	0.36	0.34^{***}	0.40	0.15^{***}	0.16	0.17^{***}	0.18
Spain 0								
Tropical logs	0.98^{***}	1.61	0.00	-0.01	1.34^{***}	2.65		
Temperate logs	0.50	0.38	0.75^{*}	0.94	1.20^{*}	1.61	2.27^{***}	5.80
Tropical lumber	0.59^{**}	0.75	0.92^{***}	1.47	0.12^{**}	0.12	0.19^{**}	0.20
Temperate lumber	0.94^{***}	1.49	0.68^{***}	0.94	0.34^{***}	0.39	0.24^{***}	0.27
Tropical plywood	0.56	0.61	1.90^{***}	5.42			1.09^{***}	1.90
Temperate plywood	0.63^{***}	0.83	1.08^{***}	1.91	0.31^{**}	0.35	0.53^{***}	0.69

Note: *** P<0.01, ** P<0.05, * P<0.10. α_5 and α_6 are the estimated long run effects of the adoption and enforcement of EUTR, and γ_5 and γ_6 are the corresponding short run effects. Elas. stands for the percentage effect of EUTR on import quantities. The number following state name is its score on efforts to tackle illegal logging reported in the WWF Government Barometer (2014) ranging from 0 (lowest efforts) to 16 (highest efforts).



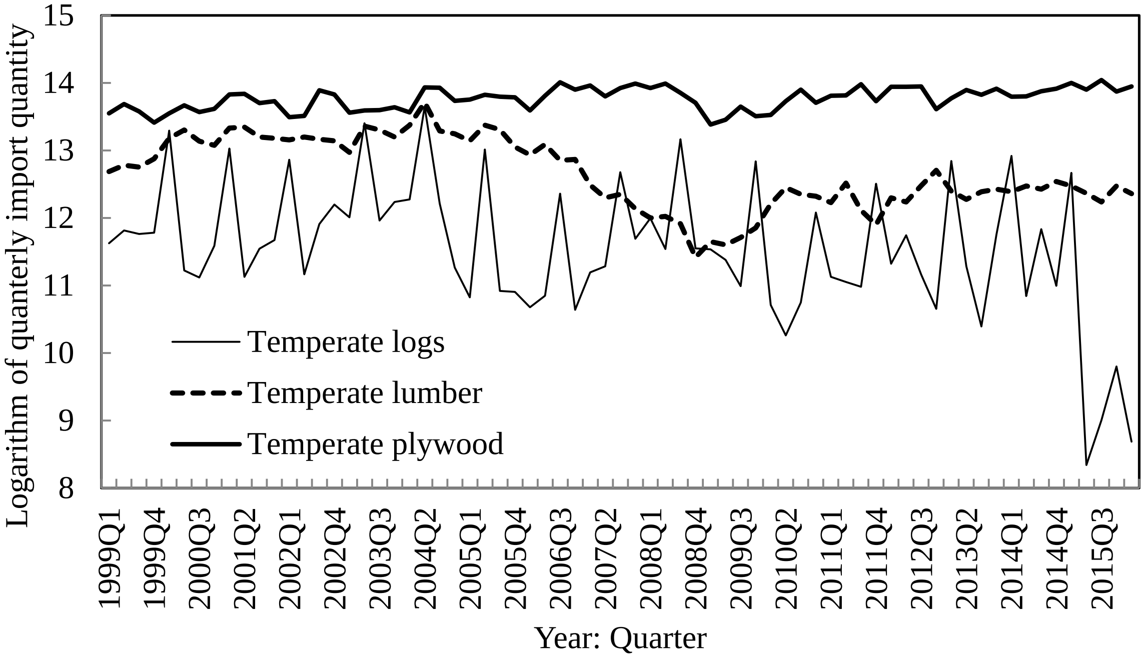


Fig. 3.1 Natural logarithm-transformed quarterly import quantities (100KG) by product in United Kingdom: 1999Q1-2016Q1
Data source: Dataset of European Commission (Eurostat, 2016).

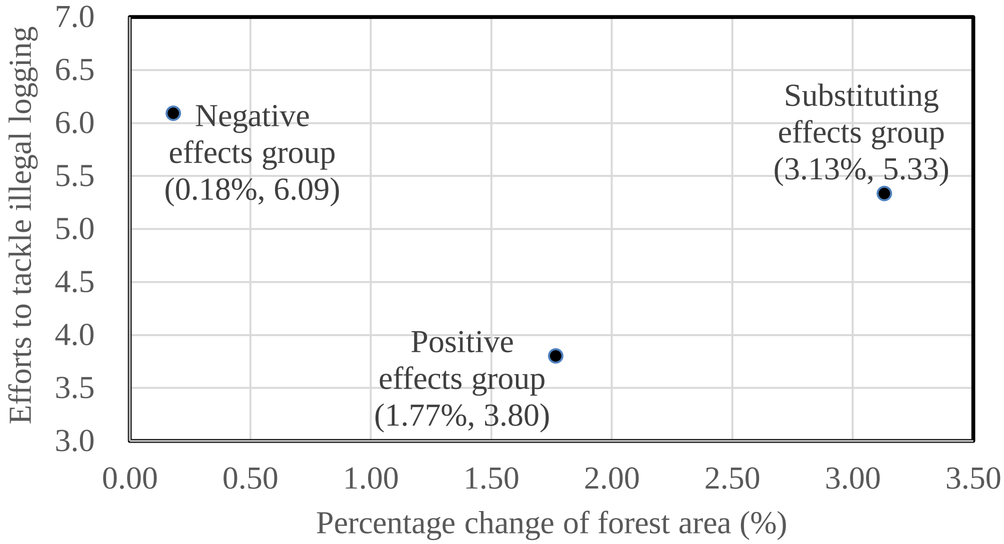


Fig. 3.2 Groups' percentage changes of forest area (%, from 2010 to 2015) and efforts to tackle illegal logging (0-16)
Note: Forest includes both natural and planted forests. Score on efforts to tackle illegal logging is average score of states reported in the WWF Government Barometer (2014) ranging from 0 (lowest efforts) to 16 (highest efforts).

Fig. 3.3 EU member states by the effects of EUTR on imports.

Chapter 4. Voluntary Partnership Agreement and Ghana's timber products exports

Abstract

Ghana is the first country to sign and ratify a Voluntary Partnership Agreement (VPA) with the European Union. Under the VPA, Ghana is expected to verify its timber exports to the EU member states coming from legal sources. In this paper, we use the gravity model to quantify the impacts of VPA on Ghana's exports to the EU and other countries by timber product. Our results show that Ghana increased its exports of non-coniferous roundwood to both the EU and the other countries. Furthermore, its exports of non-coniferous sawnwood, plywood, and veneer sheets decreased significantly to the EU communities. However, the VPA did not have significant effects on Ghana's non-coniferous sawnwood, plywood, and veneer sheets exports to the non-EU destinations.

Keywords: Exports, timber products, gravity model, Voluntary Partnership Agreement

1. Introduction

The issue of illegal logging, particularly in the context of tropical products, has been prominent on the international agenda in the last few decades. The negative environmental impacts of illegal wood fiber sourcing include forest degradation, loss of biodiversity, and emissions of greenhouse gasses (Miles and Kapos, 2008). Economic impacts include depressing forest product prices, loss of government revenues, and rural poverty (World Bank, 2002; Li et al., 2008). In recent years, the world's leading economies have tried to use trade regulations to curb illegal logging. In 2003, the European Commission (EC) presented the EU Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan. A cornerstone of the Plan is Voluntary Partnership Agreements (VPAs) between the EU and tropical timber producing and exporting countries.

Under a VPA, the partner country is expected to develop a legality assurance system (LAS) to verify that its timber exports to the EU come from legal sources. The EU provides assistance to the partner country to develop a viable timber tracking and licensing system, and in strengthening the governance capacity (Jonsson et al., 2015). Although VPAs are voluntary, it is legally binding on both sides once ratified. Each VPA requires a definition of "legally-produced timber," and the LAS is expected to build in line with the requirements of the definition (Attah et al., 2009). Hence, VPAs build on national ownership, and their implementation varies from country to country. By the end of 2016, six countries (Cameroon, Central African Republic, Ghana, Indonesia, Liberia, and Republic of the Congo) have signed a VPA with the EU and are currently developing the LAS needed to control, verify, and license legal timber. Nine additional countries are in the process of negotiating VPAs with the EU. They are Côte d'Ivoire, Democratic Republic of the Congo, Gabon, Guyana, Honduras, Laos, Malaysia, Thailand, and Vietnam.

Ghana was among the first countries to initiate negotiations and the first one to sign a VPA with the EU. After almost three years' negotiation, the VPA was signed in November 2009 and ratified in March 2010. The rationale behind the VPA is that Ghana was unable to fully implement law enforcement in curbing illegal logging on its own (Attah et al., 2009). In the last three decades, Ghana implemented several policies aimed at sustainable forest management, including a complete ban on unprocessed log exports in 1995, a reduction in the nation's annual allowable cut, and the imposition of an export levy on air-dried sawnwood. Yet, studies found an annual illegal harvesting level of 2.3-2.7 million m^3 or 70% of the total timber production in the country (Hansen and Treue, 2008). It is expected that the implementation of law enforcement in Ghana would be enhanced through use of international market levers contained in the VPA.

The implementation of VPA may affect Ghana's competitive position in timber exports. With the enactment of VPA, one may assume the disappearance of illegal supply. Theoretically, this would shift Ghana's excess supply curve upward, resulting in an an increase in the equilibrium market price and a decrease in the equilibrium export quantity, reducing producer surplus. The VPA does not embody a commitment by the EU to purchase (potentially more expensive) Ghanaian certified timber. Moiseyev et al. (2010) conducted a simulation on the impact of the VPAs between EU and six countries using the EFI-GTM global forest sector model, and found that implementation of VPA reduce harvests, increase wood prices, and reduce industrial productions in the exporting countries. Nevertheless, after almost seven years of implementation, there are no empirical studies quantifying the impacts of VPA on exports.

The objective of this study is to quantify the effects of VPA on Ghana's exports of timber products using the gravity model. Specifically, we estimate and compare the impacts of VPA on quantities exported to the EU and non-EU regions in four major timber products——non-coniferous industrial roundwood, non-coniferous sawnwood, plywood, and veneer sheets. In this way, we can detect the impacts of VPA on Ghana's exports to the EU communities, and the possible diversion of timber exports to destinations with less or no regulation, i.e. the non-EU countries. The next section presents Ghana's timber harvesting regulations and VPA implementation. Section 3 depicts the recent trends in timber products exports. Section 4 provides the gravity model specification and data. Section 5 presents the results. The final section concludes with some discussion.

2. Timber Harvesting Regulations and VPA Implementation in Ghana

Ghana relies heavily on the extraction of its natural resources to meet its economic growth objectives. Forest's contribution to Ghana's GDP fluctuated over the years and peaked at 14% in 2003 (Fig. 4.1). There was a decrease in the percentage of forest's contribution to GDP after the implementation of VPA in 2009, but the percent contribution went up again to 9.8% in 2015. The large majority of timber resources are situated in the high forest zone in the south accounting for about a third of Ghana's land area (8.2 million hectares). About 22% of the high forest zone (1.8 million hectares) is gazetted as forest reserves (permanent forest estate) in which no other land use is permitted (Nolan and Ghartey, 1992; Adam et al., 2006). The remaining areas are collectively termed "off-reserves" where other land use is permitted. Little closed natural forest left in the off-reserves. It has been converted to agricultural dominated farm land. However, a large number of trees, mainly remnants of the natural tropical high forest, are found dispersed in this agricultural landscape. Legally, timber harvesting takes places in both the forest reserves and off-reserves.

In Ghana, about 95% of lands and natural trees, both on- and off-reserves, are owned by the Stools, the traditional authorities, each headed by a Chief. And the remaining 5% are held by the State (Boni, 2005). The 1962 Concession Act vests all rights to natural trees in the President in trust for the Stools (Hansen et al., 2015; Boakye, 2015). Under this regime, the government (in practice the Ghana Forestry Commission) grants logging rights in both on- and off-reserve areas to private timber companies. Private companies pay a fee for the harvesting rights, and the harvesting fee is shared between the Forestry Commission, the Stools, and the local government. These private timber companies, called formal sector in Ghana, consist of both integrated firms with logging and wood processing facilities as well as small logging firms which supply logs to the former. However, the annual allowable cut is far below the actual harvesting in the formal sector. Using both official reported figures and estimated harvest figures, Boakye (2015) found that between 2000 and 2011, the annual average illegal logging in the formal sector is 0.78 million m^3 or 104% of the legal harvest.

The formal sector is export-oriented due to the higher export than domestic market price (Karsenty, 2003). While export trade has been encouraged, little attention has been paid to the supply of timber products to the local market. The government directed private timber companies to sell at least 20% of their timber production on the domestic market in 2005 (Nanang, 2010). However, this 20% is inadequate to meet the demand for timber products in the domestic market. Currently, about 80%-90% of the domestic lumber demand is met by chainsaw operators, who convert trees into lumber at the felling site with chainsaws (Domson et al., 2007; Hansen, 2010). These chainsaw operators work without a concession or permit since the 1998 Timber Resources

Management Regulations banned the use of chainsaws for commercial purposes as well as the transport and marketing of chainsaw lumber (Frank and Hansen, 2014). The illegal chainsaw operators are armed and mostly operate at night and non-working hours in virtually every forest area (Boakye, 2015). The assessed illegal harvesting by chainsaw operators is between 1.7 to 2.5 million m^3 annually (Birikorang et al., 2001; Marfo, 2010).

Ghana has tightened its forest law compliance with task forces on combating illegal logging since the 1990s. However, these measures have generally not proven effective in Ghana because of the ambiguous tenure system, insufficient supply compared to demand in the domestic market, corruption, and interference of powerful actors (Frank and Hansen, 2014; Hansen et al., 2015).

The VPA assists law enforcement by exerting external pressure through control of exports and domestic capacity building. During the negotiation process, Ghana organized several multi-stakeholder consultative forums made up of representatives from government, civil society, private sector, and national certification working groups. Illegal logging is defined as timber rights allocation, harvesting operation, transportation, processing, and trade in contravention of the LAS outlined in the VPA between Ghana and EU. Timber products covered under the VPA are primary wood and articles of wood such as roundwood (in the rough), sawnwood, plywood, and veneer sheets (GoG-EU, 2009). Although Ghana is marking some progress in implementing its VPA, it takes a long time for the FLEGT licensing to come into effect. It is expected that in September 2014 Ghana would issue its first FLEGT license under the VPA. However, it is still working on rolling its wood tracking systems needed to issue the FLEGT licensing which was expected to complete by the end of February 2017.

3. Trends in Timber Product Exports

The forestry trade flows dataset of Food and Agricultural Organization (FAO) reports Ghana's export values of timber products. Figs. 2 and 3 show the value of Ghana's timber products exports from 1997 to 2014. Roundwood exports grew from US $3.9 million in 1997 to US $212.5 million in 2014 (nominal values). The average annual export value was US $38.7 million. There was significant fluctuation as indicated by the sharp increases of export values in 2011 and 2014 which reached more than US $200 million. This was attributed to the high export values of US $168.9 million to India in 2011 and US $172.2 million to China in 2014. In terms of the share in total timber exports, roundwood exports remained around 6.6% of the total without including the two extreme values in 2011 and 2014.

Sawnwood exports grew from US $125 million in 1997 to US $246.8 million in 2013 which followed by a sharp decrease to US $52.2 million in 2014. The average annual export value was US $113 million. The share of sawnwood exports to total timber exports was 64% in 1997, and the share dropped to an average level of 36% during 2006 to 2014. The same as roundwood exports, there were large fluctuations in the export values of sawnwood since 2006.

From 1997 to 2005, there was a relatively stable increase in plywood exports, from US $4.7 million to US $12.4 million. Then, there was a sharp increase in 2006 and large fluctuations since. The peak export value was US $190 million in 2012 which was attributed to the high export value of US $141.5 million to Nigeria. In terms of share in total timber exports, plywood remained around 10% on average without considering the extreme value and share in 2012.

Ghana exported US $62 million of veneer sheets in 1997, which was 32% of total timber exports. And the export share of veneer sheets was relatively stable from 1995 to 2005 at an average annual level of 35%. Although there was a slight increase in the average export value since 2006 compared to that of the 1997 to 2005 period, the export share decreased to 23% on average. The peak value was US $190 million in 2012, which was attributed to the high export value of US $141.6 million to Benin.

Fig. 4.4 shows the composition of Ghana's timber products exports by major destinations. The EU and Asia were the top export destinations of roundwood coving more than 96% of total roundwood exports except in 2013 when Ghana exported a sizeable share of roundwood to Niger (US $4.8 million). However Niger was a relatively new export destination of roundwood since 2010 when it imported US $0.7 million from Ghana. A notable fact is that Ghana had a nonnegligible market diversion of roundwood exports from the EU to Africa since 2006. The average share of EU's imports dropped from 75% during 1997 to 2006 to 10% during 2007 to 2014. On the other hand, the share of Asia's imports increased from 19% to 83% during the same period.

In 1997, Ghana exported more than 88% of its sawnwood to the EU market. There was a continuous decrease in EU's market share which reduced to 13% in 2014. Meanwhile, there was a steady increase in Ghana's sawnwood exports to Asia, the percentage share increased from 3.5% in 1997 to around 43% during the 2007 to 2014 period. Besides, Africa and the United State were the other two emerging and expanding export destinations of Ghana's sawnwood exports. Overall, there were both value and share decreases in Ghana's exports of sawnwood to EU while Asia became the largest export destination in recent years.

The EU and Africa were Ghana's top export destinations of plywood exports. In 1997, Ghana exported more than 80% of its plywood to the EU market. And EU's market share peaked at 95% of total plywood exports in 2004. However, there was a sharp decrease since 2006 which resulted in an average annual share of 8%. Ghana exported 1.6% of its plywood to Africa in 1997 while the percentage share increased to more than 80% after 2006. Overall, there were both value and share decreases in Ghana's exports of plywood to the EU while Africa became the largest export destination since 2006. The two largest export destinations in Africa were Niger and Nigeria.

In 1997, Ghana exported more than 84% of its veneer sheets to the EU market. There was a continuous decrease of EU's market share which reduced to 2% in 2013. This is because that Ghana exported around 92% of veneer sheets to the Africa market which was mainly to Benin. Africa began to become the top export destination of Ghana's veneer sheets since 2006. Meanwhile, there was a steady decrease of the US's market share in Ghana's veneer sheets exports, which has been particularly prominent since 2008. This may be because of the implementation of the Lacey Act Amendment of 2008 (LAA) in the US which bans for the first time the imports of any tree species illegally obtained in the country of origin.

4. Model Specification and Data

This study models Ghana's exports as a function of factors that might create export resistance or promote export between Ghana and its major destinations by timber product. The Gravity model is often estimated for trade joining imports and exports (Kangas and Niskanen, 2003; Hujala et al., 2013; Buongiorno, 2015). We apply it to Ghana's timber product exports separately as we focus on disaggregated trade data and Ghana is a net exporter in these timber products. Following the study of Zhang and Li (2009), the export flow is modeled as

$$T_{it} = e^{\alpha_i} \prod_m X_{imt}^{\beta_m} \prod_n e^{\gamma_n D_{int}} \varepsilon_{it} \quad (1)$$

or in a log-linear form

$$lnT_{it} = \alpha_i + \sum_m \beta_m lnX_{imt} + \sum_n \gamma_n D_{int} + ln\varepsilon_{it} \quad (2)$$

where T_{it} is the value of timber product exports between Ghana and destination i in year t, X_{imt} is the mth explanatory variable for destination i in year t, D_{int} is the nth dummy variable for destination i in year t, ε_{it} is the error term, and α_i, β_m, and γ_n are parameters to be estimated. Equation 2 is often estimated by ordinary least squares (OLS) on pooled cross-sectional data. However, OLS is criticized for not controlling heterogeneity. Recently, studies propose panel data analysis as it can capture the relationships among variables over time and possible unobservable individual effects (Mátyás, 1997; Egger, 2000). A Poisson pseudo-maximum likelihood (PPML) estimation method is proposed to avoid estimation bias in the presence of heteroskedasticity (Santos Silva and Silvana, 2006, 2011). We estimated the gravity model using these different methodologies.

Our dependent variables are export values by product and year. The trade data is from the FAO. For roundwood exports, our data covers the trade values between Ghana and five major exporting destinations, i.e. Germany, Ireland, India, United Kingdom, and China, from 2002 to 2014. These countries account for more than 80% of total roundwood exports on average from 2002 to 2014[8]. We only cover data from 2006 to 2014 in the model estimation of sawnwood, plywood, and veneer sheets. Data before 2006 is excluded from estimation for two reasons. One is that there were significant trend breaks in export values as indicated in section 3. The other is that Ghana experienced dramatic market diversion from EU to non-EU regions like Asia or Africa which resulted in many new destinations since 2006. There are 34, 14, and 30 exporting partners accounting for more than 90%, 96%, and 92% of Ghana's total sawnwood, plywood, and veneer sheets exports since 2006, respectively.

[8] There were large fluctuations in the market share of these five countries in terms of total roundwood exports. They accounted for more than 90% in most of the years from 2002 to 2014 except for that in 2005 (55%) and 2013 (41%). We did not include other partners to avoid large number of missing values as Ghana exported a sizeable amount to the other destinations only in certain years.

Our independent variables are economic size, per-capita GDP, distance, exchange rate, exchange rate volatility, and two dummy variables for the implementation of VPA. All variables except dummies take the natural logarithms. GDP is used as a proxy for a country's economic size. Large countries are expected to absorb more imports from Ghana. Per-capita GDP is an indicator for importer's per-capita income. The coefficient of per-capita GDP is positive if the imported product tends to be the luxury good and negative if it tends to be necessities (Bergstrand, 1989; Schumacher and Siliverstovs, 2006). GDP and per-capita GDP data are from the macro-statistics dataset of FAO. Distance captures transportation costs, information and search costs (Loungani et al., 2002; Martínez-Zarzoso and Nowak-Lehmann, 2003). It is expected that distance has a negative effect on trade values between Ghana and its export partners. Following Zhang and Li (2009), the distance between two countries is measured in great circle distance between their capitals and the data is obtained from the economic research resources maintained by Robertson (2006).

The exchange rate used in this study is in export partner's currency per Ghanaian cedi. An increase in the exchange rate implies an appreciation of the cedi and is expected to have a negative effect on Ghana's timber product exports. Exchange rate volatility is expected to have a negative effect on exports if hedging is not possible or is costly (Ethier, 1973; Hooper and Kohlhagen, 1978; Kawai and Zilcha, 1986). In this study, we follow the concept of Dell'Ariccia (1999) which points out that if the exchange rate follows a constant trend it could be perfectly anticipated and therefore would not be a source of exchange risk. This indicates that exchange rate volatility can be measured as the moving standard deviation of first differences in the exchange rate over the prior years, which is

$$v_{it} = \sqrt{\sum_{t=1}^{m}(\Delta lne_{it} - \Delta ln\bar{e}_{it})^2/(m-1)} \quad (3)$$

where e_{it} is the bilateral exchange rate, m is the number of years and equals 2 in this study[9]. Exchange rate data are from the Economic Research Division of Federal Reserve Bank of St. Louis and Economic Research Service of US Department of Agricultural exchange rate data set. All the exchange rates are in nominal values to be in consistent with nominal export and GDP values.

In this study, the VPA is legally binding between Ghana and EU, and a dummy variable equaling to 1 after its implementation is used for EU countries to control for the impact of the VPA on Ghana's timber product exports to the EU communities. Moreover, Ghana may export its products to destination without the enforcement of VPA. To assess this possibility, we adopt another dummy variable equaling to 1 after VPA's implementation for countries outside the EU. It is expected that the VPA would have negative effects on Ghana's exports to the EU if the VPA works in curbing illegal logging.

5. Estimation Results

For the purpose of comparison, Equation 2 is estimated using several methodologies: pooled OLS, fixed effects model, random effects model, and PPML method. Tables 4.1-4 present the results for roundwood, sawnwood, plywood, and veneer sheets exports, respectively. The Hausman test suggests that fixed effects model is preferred than random effects model for the exports of roundwood and sawnwood, and that random effects model is preferred for the exports of plywood and veneer sheets. To check the adequacy of the estimated models, we performed a heteroskedasticity-robust RESET test (Ramsey, 1969). The test results indicate that sawnwood export model estimated using the OLS specification is inappropriate, and the PPML specification is inappropriate in the estimations of plywood and veneer sheets models.

[9] Similar to the period adopted in Chit et al. (2010).

The estimation results for roundwood exports in Table 4.1 show that the models are reasonably good with goodness of fit above 0.6. The fixed effects model reports similar results as the pooled OLS except for the coefficients of GDP and per-capita GDP. The effect of VPA on Ghana's roundwood exports to the EU is no longer significant in the fixed effects model. The PPML results are consistent with the pooled OLS in signs of estimated coefficients but with higher magnitudes.

Based on the results of the OLS model in Table 4.1, we can make the following references. First, the significant positive coefficient (2.47) of per-capita GDP suggests an increase in demand for roundwood imported from Ghana as income increases. Second, exchange rate and exchange rate volatility were positively associated with Ghana's roundwood exports. The higher exchange rate in importer's currency per Ghanaian cedi makes Ghana's roundwood relatively cheaper in global markets which would result in an increase in exports. An increase in exchange rate volatility can promote exports if exporters have the ability of hedging or to adjust trade volumes to movements in the exchange rate (Sercu and Vanhulle, 1992; Broll and Eckwert, 1999). A possible explanation of the positive effect of exchange rate volatility is that Ghana has high domestic demand of roundwood which enables its ability to benefit from exchange rate movements by reallocating roundwood between the domestic and foreign market. Third, as for the VPA variables that are interested in this study, Ghana exported more to both the EU and other destinations after the implementation of the VPA. Contrary to conventional wisdom, Ghana's participation in the VPA could have promoted its roundwood exports.

As for the export model of sawnwood, we prefer the PPML estimation than the fixed effects model since the former has a much higher p-value of RESET test and provides more meaning estimated coefficients for the GDP and distance variables. The results of the PPML model in Table 4.2 show that Ghana exported more sawnwood to more developed economics (positive coefficient of GDP) with shorter geographic distance (negative coefficient of distance). Further, exchange rate volatility was negatively associated with Ghana's sawnwood exports. When hedging is impossible or is costly in sawnwood exports, high volatility in exchange rates between importer country and Ghana would discourage sawnwood trade between the two countries. Finally, Ghana exported sawnwood less to the EU communities after the implementation of VPA and the positive effects of VPA on the exports to other destinations outside the EU was insignificant at the 10% level. Therefore, there is no sufficient evidence that there were market diversion to the non-EU destinations of sawnwood exports.

For the export model of plywood, the estimators of random effects model are similar in magnitudes as the pooled OLS estimation except that per-capita GDP and exchange rate are insignificant at the 10% level. Based on the OLS estimation in Table 4.3, countries with higher income and shorter geographic distance imported more plywood from Ghana. But, there was no significant evidence that Ghana would export more to larger economies. Further, both exchange rate and exchange rate volatility had significant negative effects on Ghana's plywood exports. Moreover, the implementation of VPA had significant negative effects on Ghana's exports of plywood to the EU markets. The negative effect of the VPA on plywood exports to the non-EU destinations was insignificant at the 10% level. The implementation of VPA had a larger negative impact on the exports of plywood to the EU (-1.60) compared to that of sawnwood exports (-1.18).

The OLS and random effect models show that main influencing factors of Ghana's veneer sheets exports were GDP, distance, as well as the VPA. Although the coefficient of exchange rate volatility was insignificant in pooled OLS estimation, the random effects model reported an elasticity of -3.67 of exchange rate volatility on the export value of veneer sheets at the 1% significant level. The same as sawnwood export, Ghana exported more veneer sheets to more developed economies with shorter geographic distance. As for the effects of VPA on veneer sheets exports, we find a significant negative impact on the exports to the EU communities while the negative effects to other destinations were insignificant, which are the same case as on the exports of plywood.

6. Conclusion and Discussion

The study is a first attempt to quantify the effects of VPA on Ghana's exports of timber products. We use the gravity model to assess the determinants of Ghana's timber product exports in general and to quantify the effects of VPA separately as to EU and the non-EU destinations. Overall, the model fits properly to our objectives.

The exports of all timber products to the EU communities decreased both in values and shares since 1997. There were trend breaks since 2006, with market diversion from EU to Asia in roundwood and sawnwood exports and to Africa in plywood and veneer sheets exports. Our gravity model results show that the general variables such as GDP, per-capita GDP, exchange rate and its volatility, and distance played different roles in Ghana's exports of different timber products. As expected, the VPA had significant negative effects on Ghana's exports to the EU communities in terms of sawnwood, plywood, and veneer sheets, and there is no significant evidence that the exports to other destinations had gone up in sawnwood and reduced in plywood and veneer sheets. The interesting result is that the VPA had significant positive effects on Ghana's roundwood exports to both EU and the other destinations. There were large fluctuations in roundwood export price while about 10 times increase in export quantity from 0.04 million m^3 to 0.4 million m^3 from 2010 to 2014 (FAO, 2016).

Since the ratification of the VPA between Ghana and the EU, Ghana has been working on building of the LAS to track its timber product productions and exports. Our results indicate that this supply side measure at least works in the exports of some primary processed timber products, i.e. sawnwood, plywood, and veneer sheets, as indicated by decreased exports to the EU and lack of significant evidence supporting market diversion to the non-EU markets. However, although we point out the effects of VPA on exports by timber product, another priority for future research is to understand domestic producer responses attributed to these export trend changes. There is still a long way to go for the overall and long run effectiveness of VPAs in achieving reductions in illegal logging.

Table 4.1 Gravity model for Ghana's roundwood exports

	OLS ln (Exports)		Fixed Effects ln (Exports)		PPML Exports	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
ln (GDP)	0.11	0.16	-12.40*	6.98	1.15**	0.49
ln (GDP per capita)	2.47***	0.86	16.38**	7.04	5.78*	3.16
ln (Exchange rate)	2.87***	0.86	2.89*	1.46	5.83**	2.83
ln (Exchange rate volatility)	9.01**	3.67	9.27**	4.07	11.59*	4.82
ln (Distance)	-1.15	1.26			3.75	2.42
VPA_EU	1.01*	0.54	1.48	0.91	1.69	1.40
VPA_other	3.19***	0.94	2.69***	0.92	0.49	0.98
Constant	-11.73	19.05	17.67	33.36	-102.60*	56.52
No. of observations	61		61		65	
No. of groups			5			
R^2	0.61		0.69			
RESET test p-value	0.16		0.28		0.89	

Table 4.2 Gravity model for Ghana's sawnwood exports

	OLS ln (Exports)		Fixed Effects ln (Exports)		PPML Exports	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
ln (GDP)	0.52***	0.05	1.37	1.28	0.54***	0.18
ln (GDP per capita)	-0.20**	0.09	1.57	1.33	-0.13	0.24
ln (Exchange rate)	-0.01	0.04	1.07*	0.60	-0.01	0.04
ln (Exchange rate volatility)	-6.53***	1.97	-5.85**	2.32	-5.39***	1.90
ln (Distance)	-1.59***	0.22			-1.05***	0.32
VPA_EU	-1.18***	0.22	-0.48	0.38	-1.22***	0.24
VPA_other	-0.07	0.24	-0.49	0.38	0.46	0.50
Constant	16.45***	1.55	-27.97***	6.85	11.69***	1.93
No. of observations	295		295		306	
No. of groups			34			
R^2	0.29		0.70			
RESET test p-value	0.07		0.10		0.47	

Table 4.3 Gravity model for Ghana's plywood exports

	OLS ln (Exports)		Random Effects ln (Exports)		PPML Exports	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
ln (GDP)	-0.02	0.13	-0.09	0.35	0.78***	0.23
ln (GDP per capita)	0.54**	0.24	0.83	0.63	-0.55	0.43
ln (Exchange rate)	-0.13***	0.05	-0.16	0.14	0.04	0.06
ln (Exchange rate volatility)	-7.89***	3.02	-7.70***	2.51	-1.34	5.00
ln (Distance)	-1.41***	0.23	-1.71***	0.55	-1.28***	0.20
VPA_EU	-1.60***	0.41	-1.29***	0.39	-1.24**	0.58
VPA_other	-0.45	0.37	-0.54**	0.27	0.13	0.41
Constant	14.15***	1.34	14.77***	2.87	12.40***	1.05
No. of observations	114		114		126	
No. of groups			14			
R^2	0.38		0.36			
RESET test p-value	0.13		0.89		0.00	

Table 4.4 Gravity model for Ghana's veneer sheets exports

	OLS ln (Exports)		Random Effects ln (Exports)		PPML Exports	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
ln (GDP)	0.60***	0.07	0.64***	0.17	0.43***	0.09
ln (GDP per capita)	0.04	0.09	0.17	0.22	-0.09	0.13
ln (Exchange rate)	0.03	0.06	0.07	0.12	-0.40**	0.16
ln (Exchange rate volatility)	-2.76	2.13	-3.67***	0.66	-8.29	6.20
ln (Distance)	-1.04***	0.22	-1.17***	0.35	-1.30***	0.23
VPA_EU	-1.07***	0.24	-1.21***	0.25	-1.07***	0.30
VPA_other	-0.24	0.23	-0.24	0.22	-0.33	0.31
Constant	7.34***	1.96	6.66**	2.75	14.43***	2.10
No. of observations	254		254		270	
No. of groups			30			
R^2	0.28		0.28			
RESET test p-value	0.09		0.97		0.01	

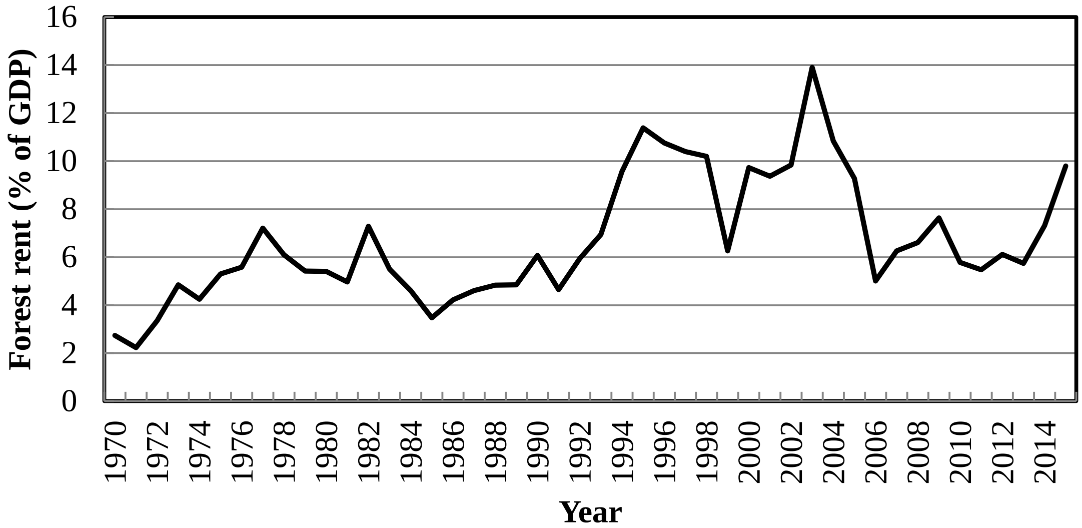


Fig. 4.1 Forest product sector's contribution to Ghana's GDP

Data source: World Development Indicators (World Bank, 2017)

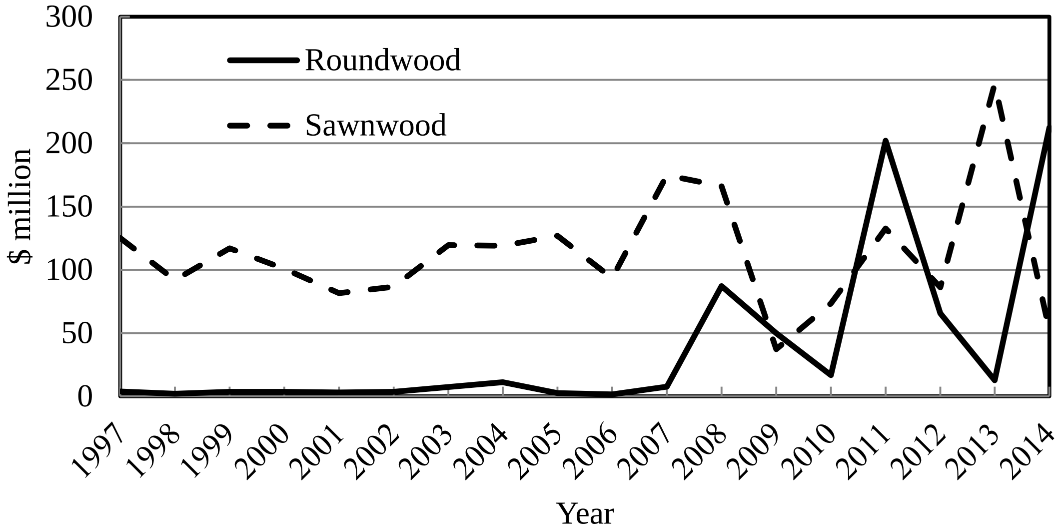


Fig. 4.2 Export value of Ghana's roundwood and sawnwood (nominal values)

Data source: FAO (2016).

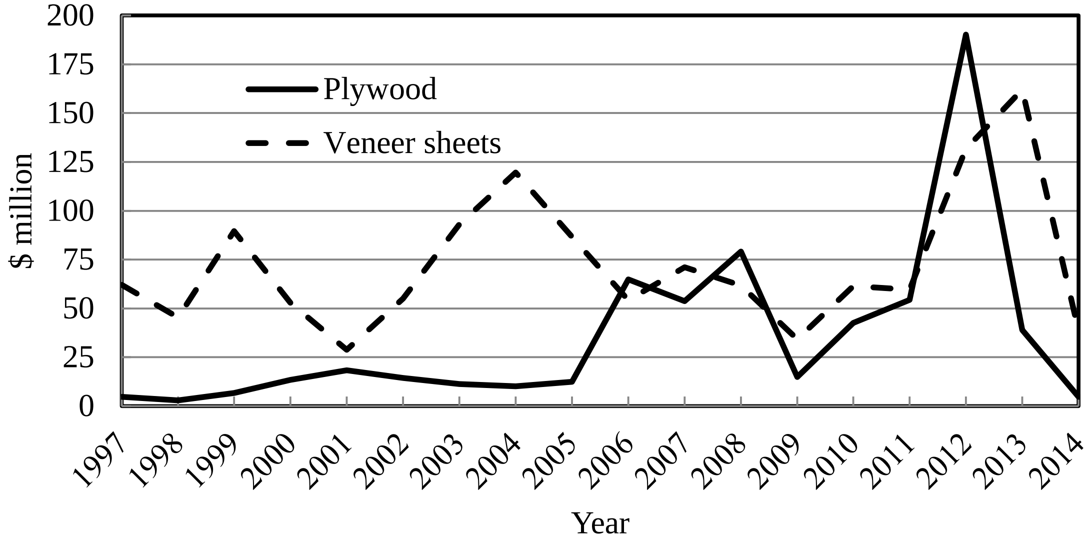
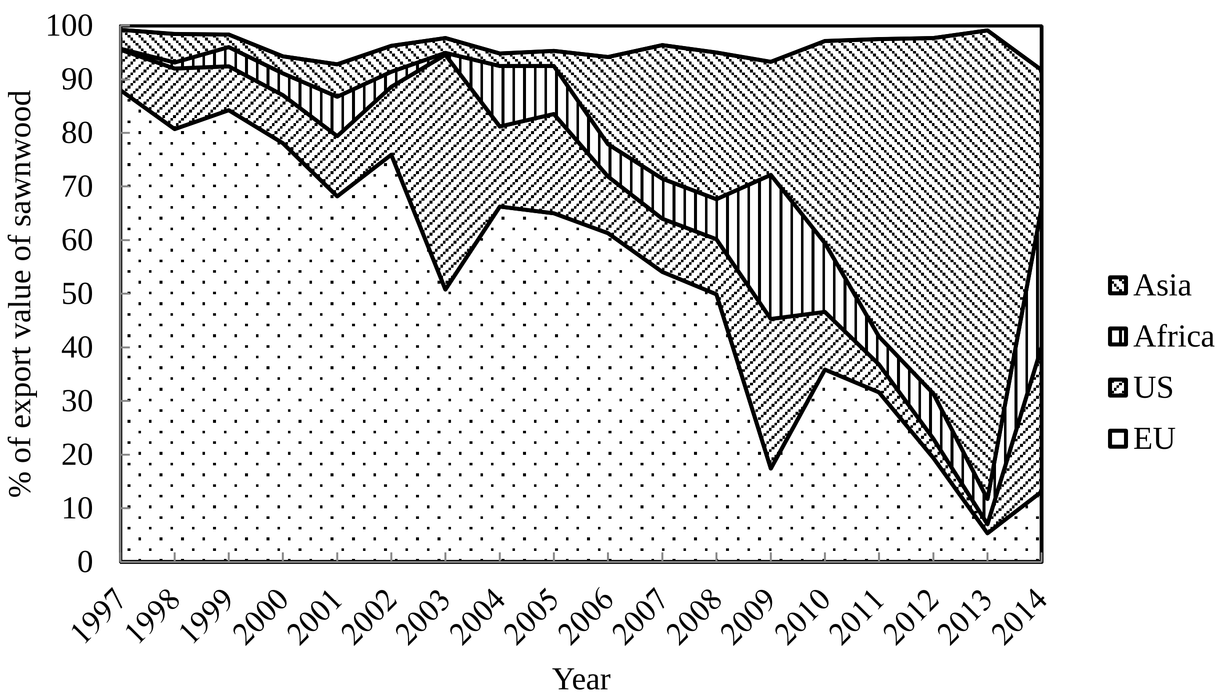


Fig. 4.3 Export value of Ghana's plywood and veneer sheets (nominal values)
Data source: FAO (2016).


100
90
80
70
60
50
40
30
20
10
0
% of export value of roundwood
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year
Asia
Africa
US
EU


100
90
80
70
60
50
40
30
20
10
0
% of export value of sawnwood
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year
Asia
Africa
US
EU

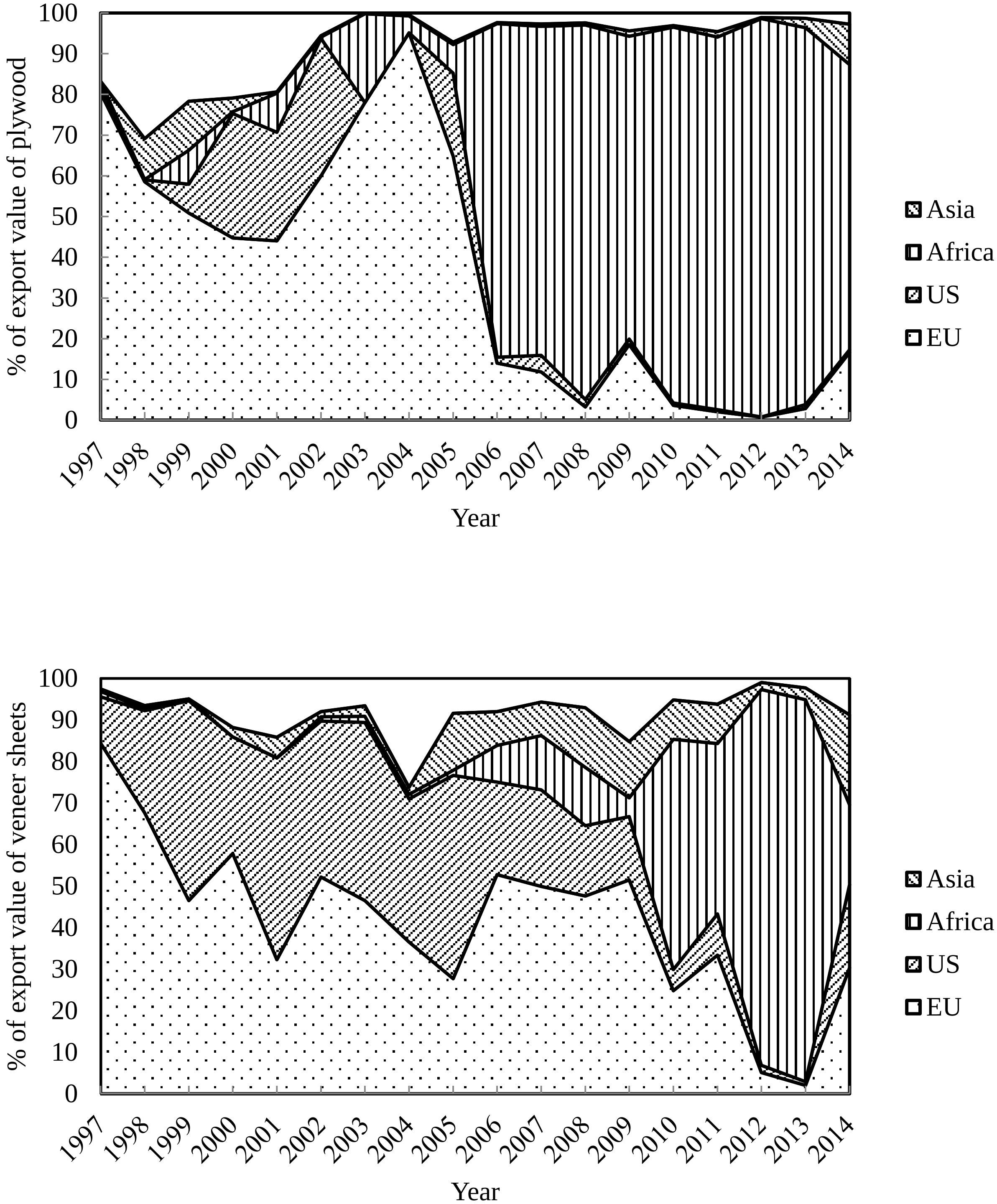


Fig. 4.4 Composition of Ghana's roundwood, sawnwood, plywood and veneer sheets exports by major destinations

Data source: FAO (2016).

Chapter 5. Conclusions

We used a vertical log-lumber market model to estimate the effect of Russian log export tax covering two products and two markets. From a national perspective, the export tax on softwood logs is suboptimal from the Russian perspective, owing to its dominant position as a log exporter and ability to discriminate against foreign log buyers. Both theoretical and empirical analyses show that the log export tax has a negative effect on domestic log price which in turn stimulates Russian lumber production and exports. Overall, the loss in logging sector is transferred to domestic lumber producers, domestic lumber consumers, and treasury. As Russia entered the World Trade Organization in 2012, it had to rescind its log export tax and use more non-tax barriers to limit its log exports instead. Compared to an export tax, an export quota is clearly a worse option as it harms Russian logging sector with no tax offset to the Russian treasury.

There is no direct way to measure the effects of the EUTR on curbing illegal logging in international trade. However, states with higher performance and more stringent regulation of the EUTR would be more likely to reduce their imports of timber products and consume more timber from domestic forests. In the second paper, we use quarterly trade data from 1999Q1 to 2016Q1 to quantify the impacts of EUTR on import quantities by EU member state and by product. These results provide evidence that states implemented the EUTR unevenly. Most north and central European countries decreased their imports in tropical and temperate timber products. The United Kingdom and some southeast and south-central European countries decreased their imports in tropical timber products while increased the imports in temperate plywood. North-central European countries increased their imports of tropical logs. The WWF Government Barometer (2014) assessed the EU member's efforts to tackle illegal logging. Comparing their effects and the ECM estimation results, we find that countries with higher performance on curbing illegal logging had higher possibilities to decrease their imports. Moreover, those states may turn to the domestic market for timber supply as evidenced by lower percentage increase in forest area from 2010 to 2015.

The third study is a first attempt to quantify the effects of VPA on exports of disaggregated timber products, using Ghana as a case. The exports of all timber products to the EU communities decreased both in values and shares since 1997. There were huge trend breaks from EU to Asia in roundwood and sawnwood exports and to Africa in plywood and veneer sheets exports even before the implementation of VPA. The VPA had significant positive effects on Ghana's roundwood exports to both the EU and other countries. However, the VPA had significant negative effects on Ghana's exports to the EU communities in terms of sawnwood, plywood, and veneer sheets, and there were no significant effects on the exports of these timber products to other destinations.

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