European Journal of Wood and Wood Products (2019) 77:633–643
https://doi.org/10.1007/s00107-019-01404-z

ORIGINAL

The impact of application of FSC Chain of Custody certification on global wood products trade

Zhijie Guan[1] · **Yan Xu**[1] · **Jim Ip Ping Sheong**[1]

Received: 4 April 2018 / Published online: 4 April 2019

Abstract
FSC Chain of Custody (CoC) certification effectively proves that the timber being used originates from sustainably managed forests, and a large number of wood products have been FSC CoC certified. This paper examines the impacts of the application of FSC CoC certification on the international trade of wood products. The analysis is conducted using the Heckscher–Ohlin–Vanek model, where the number of FSC CoC certificates is used to describe the level of application, and is included as an explanatory variable for national net export of wood products. The results show that the application has had significant and positive impacts on the net export of sawnwood, particleboard, plywood, wood furniture and fibreboard, while it has had significant and negative impacts on the net export of roundwood. The present findings imply that more sawnwood, particleboard, plywood, wood furniture and fibreboard in the global market have been FSC CoC certified than roundwood and veneer sheet in meeting the demand for legal products. Therefore, it is necessary to encourage more companies to apply FSC CoC certification to roundwood and veneer sheet.

1 Introduction

The Forest Stewardship Council (FSC), founded in 1993, is an independent, non-profit non-governmental organization (NGO) established to promote the responsible management of the world's forests. The certification process to FSC is carried out by accredited independent third parties such as Bureau Veritas Certification (http://www.bureauvitas.com) FSC chain of custody (CoC) certification is an integral part of FSC forest certification. FSC forest certification also includes FSC forest management certification. FSC CoC certification has been specifically designed for wood products. Its objective is to assure that the wood or the forest product purchased can be tracked accurately back to its source in the forest. Its concept is to ensure that certified wood products really come from an environmentally certified source (Upton and Bass 1996; Viana et al. 1996; Vogt et al. 2000). FSC CoC certification is a voluntary program based on the belief that consumers of wood products are likely to prefer products from organizations committed to protect the natural environment (Miles and Covin 2000; Styles et al. 2012). FSC CoC certification is expected to improve forest management by providing participating companies with marketing incentives and an access to niche markets or price premiums (Upton and Bass 1996; O'Brien and Teisl 2004; Aguilar and Vlosky 2007; Aguilar and Cai 2010; Yamamoto et al. 2014). Many companies in some countries have applied FSC CoC certification. Henrya and Tysiachnioukb (2018) analyzed Russia's response to the standards of FSC CoC certification. Pinto and McDermott (2013) used a case study to examine the application of FSC CoC certification in Brazil. Espinoza et al. (2012) checked the application benefit of FSC CoC certification for U.S. hardwood lumber manufacturers. Riera et al. (2007) analyzed the application of FSC CoC certification in Spain.

FSC CoC certification has an impact on the international trade of wood products. Its traceability system for capturing, processing and providing consumer relevant information about wood products enables certified wood products to successfully enter the European and American markets, because these products meet the requirements of sustainability or legality (Vidal et al. 2005; Owari et al. 2006; McDermott 2012; Brack 2014; McDermott et al. 2015; Guan and Gong 2015), and it also enables companies to establish new business relationships with a consequent increase in sales and increase in their benefits (Galati et al. 2017; Marasenia et al. 2017; Guan and Xu 2018). While some scholars suggested that the FSC CoC certification

✉ Zhijie Guan
zhijie.guan@163.com

[1] School of Business, Changzhou University, Changzhou 213164, People's Republic of China

has become a new trade barrier. Guan et al. (2010) analyzed the substitution relationship on certification and duty through an empirical analysis. Eriksson et al. (2007) suggested that FSC CoC certification influences the international competition of the Swedish forestry sector. Qiu and Yang (2007) pointed out that FSC CoC certification weakens the competitiveness of China's wood products and greatly affects their exports. Gan (2005) used the CGE (computable general equilibrium) model to analyze the impact of FSC forest certification on international trade of forest products, and he suggested that the FSC CoC certification undermines the balance of global trade in forest products.

The impacts of FSC CoC certification on the trade of wood products has been studied extensively. While some studies suggest that FSC CoC certification has hindered the trade of wood products, others suggest that FSC CoC certification promotes the trade of wood products. However, previous research mainly considered the impacts of FSC CoC certification on the bilateral trade of wood products (Marasenia et al. 2017; Tricallotis et al. 2018), and analyses of the impacts on the global trade using the factor endowment theory of trading region are few. The comparative advantage of a country is determined by its endowments of the factors of production (land, labor, and capital). A country is said to have comparative advantages in goods that are produced with factors of production that are locally abundant (Toit et al. 2010; Verter 2016). This is because the profitability of goods is related to the input costs. The lower the input costs, the more profitable is the production of the goods. It is cheaper to produce goods from inputs that are locally abundant than to produce goods from inputs that are scarce (Feenstra 2004). In reality, FSC CoC certification promotes the sustainable supply of roundwood, which enables the certified wood products to better meet environmental requirements and obtain a greater share of the world market (Archer et al. 2005). However, certification also increases the input costs and reduces the comparative advantage of a country's wood products (Schwarzbauer and Rametsteiner 2001; Perera and Vlosky 2006; Ebeling and Yasue 2009).

FSC CoC certification has become an effective tool to govern illegal logging (Hackett 2013; Carodenuto and Cerutti 2014; Niedziałkowski and Shkaruba 2018; Buliga and Nichiforel 2019), and certified wood products naturally meet the legal requirements (Brack 2014). All efforts against illegal logging have led to a decline in illegal logging in the world (Lawson and MacFaul 2010), and have contributed towards the increase in net trade of wood products (Guan et al. 2018). However, until now, there is no literature focused on the analysis of the impact of FSC CoC certification on the global trade of wood products. The aim of this paper is to examine the impact of the adoption of FSC CoC certification on the global trade of wood products. The analysis was conducted using the Heckscher–Ohlin–Vanek (HOV) model, where the number of FSC CoC certificates is used to describe the level of application, and is included as an explanatory variable for national net export of wood products. In the next section, the status of FSC CoC application in the world is introduced. Section 3 provides an introduction of trade of wood products. Section 4 introduces the method and data used in this study. Section 5 presents the model estimation results and discussion. Section 6 describes the limitation of the study. The last section provides a summary and the conclusion of this paper.

2 FSC CoC certification

Since CoC certification was proposed, the number of certificates has increased gradually as a number of companies have started to apply it. The number of FSC CoC certificates is greater than that of PEFC (Programme for the Endorsement of Forest Certification) CoC certificates. According to the statistics obtained from the websites of FSC and PEFC, by the end of 2017, the number of FSC CoC certificates was 33350, and the number of countries involved was 121. The number of PEFC CoC certificates was 11484 with 72 countries involved (Table 1).

FSC CoC certification is mainly applied in Europe, Asia and North America, of which Europe owns the largest number, and in 2017 the number reached 17741, accounting for more than 50% of the total number of certificates (Table 2).

FSC CoC certification has achieved a rapid development in some countries. At present, the FSC CoC certification is mainly applied in China, USA, UK, Germany, Italy, Poland, Netherlands, Japan, Brazil and Spain. In these ten countries, the number of certificates has reached 21012 in 2017, accounting for 62.6% of total certificates (Table 3). Some consumption countries such as USA, UK and Netherlands are the main countries applying the certification, processing countries such as China and Vietnam, and some production countries such as Brazil and Malaysia are also becoming the main countries applying these certifications.

Table 1 Number of CoC certificates by certification system from 2008 to 2017

Type	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
FSC-CoC number	11,847	15,713	19,313	22,230	24,414	27,127	28,248	29,764	31,622	33,550
PEFC-CoC number	4744	6171	7695	8797	9520	9996	10,591	10,744	10,976	11,484

Source: Forest Stewardship Council (http://www.fsc.org/)

3 Trade of wood products

Wood products in trade have grown rapidly under the increasing demand stimulated by the world economic growth. The status of trade in wood products is different in Asia, Africa, America, Europe and Oceania (Table 4).

Table 4 shows that Asia is a net importer of round wood, sawn wood, veneer sheet and particleboard, and a net exporter of plywood, fibreboard and wood furniture. Africa is a net exporter of roundwood, particleboard and veneer sheet, and a net importer of sawnwood, fibreboard, wood furniture and plywood. The roundwood, sawnwood, particleboard and veneer sheet of the Americas show a net export, while its wood furniture, plywood and fibreboard show a net import. Europe is a net exporter of all these products except for veneer sheet. Oceania is a net exporter of roundwood, sawnwood, veneer sheet and fibreboard, and a net importer of plywood, particleboard and wood furniture. Table 5 lists the top 5 import and export countries of wood products in the global market in 2016.

Table 5 shows that in the imports and exports of roundwood, China and Japan are the main importing countries, followed by the UK, India, and Australia. USA, New Zealand and the Russian Federation are the main exporting countries, followed by Vietnam and Australia. In the imports and exports of sawnwood, China and USA are the main importing countries, followed by Japan, UK and Germany. The USA is also the main exporting country, with an exporting amount accounted for 22.4% of the global share, and followed by Russia, Sweden, Germany and Finland, with their total exports accounted for 32.2% of the global market. In the imports and exports of veneer sheet, the USA is both the main importing and exporting country with a share of 11.7% and 11.2%, respectively of the global market. In terms of exports, the USA is closely followed by China, Canada, Ukraine and Germany. In terms of imports, it is followed by India, Germany, Italy and China. In the imports and exports of fibreboard, Germany and China are the main exporting countries with a share of 19.2% and 13.1%, respectively, while USA is the main importing country with a share of 12.8%. In the imports and exports of plywood, China is the main exporting country, and its exporting volume has accounted for 34.9% of the global market, this share is even higher than the total sum of Indonesia, Malaysia, the Russian

Table 2 Number of FSC CoC certificates in different continents from 2012 to 2017

Continent	2012	2013	2014	2015	2016	2017
North America	4591	4335	4012	3861	3679	3509
Europe	12,473	14,012	14,752	15,782	16,758	17,741
Asia	5496	6752	7433	8028	9089	10,206
South America and Caribbean	1257	1397	1431	1488	1500	1478
Africa	149	161	163	166	170	199
Oceania	448	470	456	439	426	417

Source: Forest Stewardship Council (http://www.fsc.org/)

Table 3 Top 10 countries applying FSC CoC certification in 2017

Rank	1	2	3	4	5	6	7	8	9	10
Country	China	USA	UK	Germany	Italy	Poland	Japan	Netherlands	Brazil	Spain
Share (%)	16.4	7.9	7.0	6.6	6.6	4.9	3.8	3.6	3.1	2.7

Source: Forest Stewardship Council (http://www.fsc.org/)

Table 4 Status of the net export of wood products in different continents in 2016

Continent	Roundwood (million USD)	Sawnwood (million USD)	Veneer sheet (million USD)	Fibreboard (million USD)	Plywood (million USD)	Particleboard (million USD)	Wood furniture (million USD)
Asia	− 13,688.669	− 12,173.77	− 474.017	159.52	3934.053	− 577.864	15,835.08
Africa	930.204	− 674.341	139.436	− 368.964	− 427.847	82.619	− 581.619
The Americas	4780.68	4582.876	51.885	− 983.942	− 2137.024	3.473	− 11,041.019
Europe	75.747	6415.409	− 74.759	1379.688	197.342	620.678	2220.79
Oceania	4041.097	293.615	41.515	105.27	− 193.702	− 12.026	− 1004.182

Source: International Trade Centre (http://www.intracen.org/)

Table 5 Top 5 import and export countries of wood products in 2016

Wood product	1	2	3	4	5
Roundwood					
Export	USA (14.2%)	New Zealand (8.7%)	Russian Federation (7.3%)	Vietnam (5.2%)	Australia (5.9%)
Import	China (39.3%)	Japan (11.9%)	UK (5.3%)	India (5.2%)	Austria (3.7%)
Sawnwood					
Export	USA (22.4%)	Russian Federation (9.5%)	Sweden (9.2%)	Germany (8.2%)	Finland (5.3%)
Import	China (22.1%)	USA (18.5%)	Japan (5.8%)	UK (5.2%)	Germany (3.5%)
Veneer sheet					
Export	USA (11.2%)	China (9.9%)	Canada (9.6%)	Ukraine (5.8%)	Germany (5.7%)
Import	USA (11.7%)	India (6.3%)	Germany (5.5%)	Italy (5%)	China (5%)
Fibreboard					
Export	Germany (19.2%)	China (13.1%)	Poland (6.2%)	Belgium (6%)	Thailand (5.1%)
Import	USA (12.8%)	Iran (5.3%)	Canada (4.6%)	Germany (4.5%)	UK (4.3%)
Plywood					
Export	China (34.9%)	Indonesia (14.6%)	Malaysia (7%)	Russian Federation (6.3%)	Finland (3.8%)
Import	USA (20.7%)	Japan (10.8%)	Germany (5.5%)	Korea (5.5%)	UK (4.7%)
Particleboard					
Export	Canada (21.2%)	Austria (9.5%)	Germany (8.5%)	Romania (5.6%)	France (5.5%)
Import	USA (20.6%)	Germany (9.7%)	Italy (3.9%)	France (3.7%)	UK (3.7%)
Wood furniture					
Export	China (29.3%)	Vietnam (9.7%)	Germany (9%)	Italy (7.5%)	Poland (5.9%)
Import	USA (30%)	Germany (7.2%)	UK (5.9%)	France (5.1%)	Japan (3.6%)

Source: International Trade Centre (http://www.intracen.org/)

Federation and Finland. USA and Japan are the main importing countries; their total importing share has exceeded the total sum of Germany, Korea and UK. In the imports and exports of particleboard, Canada is the main exporting country, followed by Austria, Germany, Romania and France. USA is the main importing country, followed by Germany, Italy, France and UK. In Table 5 some countries such as the USA, Japan and Germany export and import processed wood products. A possible reason for this is that these countries own relatively large domestic forest industries but a limited range of tree species. Therefore, it is necessary for them to import certain species of wood and processed wood products in order to cope with a desired range of production when exporting. Some other countries such as China and Austria have developed a large domestic forest industry, so they import roundwood and export processed products. Countries such as the Russian Federation and Australia with larger forest endowment export roundwood and import processed products. The rapid development of CoC certification in countries such as China, USA, UK and Germany has been one of the main factors that have contributed to these countries in controlling a large share of the global trade of wood products. A large part of the wood products provided by these countries are certified. These countries have in some ways influenced the gradual establishment of traceability systems of wood products.

4 Method and data

4.1 Methods

In general, the magnitude and direction in trade flows of forest products are determined by geography, size of economies, character of forest endowments and government policies. The classical trade theory states that trade happens due to differences among trading partners in their relative costs of production (Sen 2010; Panda et al. 2016). The gravity model estimates the pattern of international trade. The model has been an empirical success as it accurately predicts trade flows between countries for many goods and services (Baldwin and Taglioni 2007), but the basic form of the model consists of factors that have more to do with geography and spatiality (Deardorff 1998; Feenstra et al. 2001). One of the common relative factor abundance models is the Heckscher–Ohlin model. The Heckscher–Ohlin model presents the relationship between net trade, prices and resource endowments (Heckscher 1919; Ohlin 1933), and this model has had mixed success in empirical analyses (Estevadeordal and Taylor 2002). Although considered the basis for international trade theory (Moroney and Walker 1966), some scholars have criticized the model for its poor empirical performance (Maskus 1985; Bowen et al. 1987), but others have argued that these failures were partly due to inappropriate settings (James 1993). According to the Heckscher–Ohlin model,

the net exports of a country for a given product are a positive function of its resource endowments and a negative function of its income. There are a number of assumptions underlying the Heckscher–Ohlin model (Prestemon and Buongiorno 1997): (i) there exist fixed factors between countries; (ii) markets are competitive, and there are no trade barriers; (iii) the same technology is universally accessible; and (iv) consumption changes the same way as income changes.

Based on Learner (1984), Bonnefoi and Buongiorno (1990), and Prestemon and Buongiorno (1997) studies, we learn that the main factor determining net trade of forest products is the size of a country's forest endowment relative to the size of its economy. This approach has been prescribed by the Heckscher–Ohlin–Vanek (HOV) model (Vanek 1963). Assuming that country i has a balanced trade, that is where demand equals supply, the output of commodity j (Q_{ij}) is a function of forest endowments (E_i).

$$Q_{ij} = u_i E_i, \tag{1}$$

where u is a transformation coefficient (i.e., indicating the quantity of forest resource used per unit of output). If Eq. (1) holds for individual countries, it must also hold for the entire trading area. That is

$$\sum_i Q_{ij} = \sum_i u_i E_i. \tag{2}$$

The consumption of commodity j of a country (C_{ij}) can be interpreted as:

$$C_{ij} = S_i \sum_i Q_{ij} \tag{3}$$

where S_i is the consumption share of total output of a country in the trading area (Vanek 1968). From Eqs. (1) and (3) the net trade of country i can be interpreted as:

$$T_{ij} = Q_{ij} - C_{ij} = u_i E_i - S_i \sum_i Q_{ij}. \tag{4}$$

By using Eq. (2), Eq. (4) can be rewritten as:

$$T_{ij} = u_i E_i - S_i \sum_i u_i E_i \tag{5}$$

Equation (5) is also known as the HOV equation. Taking into consideration the factor-price equalization and identical homothetic preferences across countries, the consumption share of a country can be written as:

$$S_i = Y_i / \sum_i Y_i \tag{6}$$

where Y is income. Thus, Eq. (5) can be rewritten as:

$$T_{ij} = u_i E_i - Y_i \left\{ \sum_i u_i E_i / \sum_i Y_i \right\} \tag{7}$$

Equation (7) is of particular interest, since the ratio inside the parentheses is constant across countries. It shows that the net trade of a country for a specific commodity (T_{ij}) is a positive linear function of the country's forest endowment (E_i) and a negative linear function of the country's income (Y_i).

The HOV model has been used by some scholars in the study of the trade of forest products. Guan et al. (2018) empirically tested the impacts of international efforts to reduce illegal logging using the model, and concluded that the efforts have significantly positive effects on the examined wood products (roundwood, sawnwood, veneer sheet, fibreboard and plywood). Lundmark (2010) analyzed the comparative advantage between EU member states through an extended HOV model. The results of his study suggested that an important determinant for explaining differences in net trade of the included forest commodities is forest endowments and not domestic demand measured by income level. Liu and Tian (2007) have applied the HOV model to analyze the international trade of forest products using the data of 54 countries for the years 1995, 1998, 2001 and 2004. Their study has concluded that the international trade flows of total forest products, logs, other wood, sawnwood, wood-based panel, wood pulp and recycled paper are in line with the trade theory of comparative advantage. Environmental variables were represented by the number of environmental agreements signed by a country, and their effects on the trade flow of forest products were tested. Although the result of their test shows that the environmental variables did not have any significant effect, the conclusion does not rule out the impact of a government's environmental policy on forest products trade flow. Uusivuori and Tervo (2002) analyzed the effect of forest endowment and economic activity on the net trade of industrial roundwood and forest products, using the data of 18 OECD countries from 1977 to1998. They found limited support for the Heckscher–Ohlin model and concluded that while historical differences in forest industries and resources still exist, the part that forest resources plays in shaping the development of forest industries is becoming less important. However, their study has omitted the energy sector where forest resources are used as fuel, and which is becoming an increasingly important sector.

The impact of the application of FSC CoC certification on the global trade of wood products is the objective of this study. Following the analysis by Guan et al. (2018), the most typical way is to check trade flow within the traditional comparative advantage theory based on the Heckscher–Ohlin–Vanek (HOV) model. In order to do this, an environmental variable related to the application of FSC CoC certification in the model was introduced, and it was studied how it affects trade flow. The model was extended in a number of ways. (1) The selection of wood products is directly affected by CoC certification, therefore wood furniture is also considered besides the products defined by FAO

(Food and Agriculture Organization of the United Nations). (2) The samples are expanded to 67 countries including the main forest trade and abundant forest endowment countries, and their trade amount represents about 90% of world imports and exports. (3) The application of FSC CoC certification has started since 1994, however wood processing enterprises have truly applied CoC certification extensively since 2007. Therefore the aggregated effect of 2007–2015 is analyzed. (4) The number of FSC CoC certificates is used to describe the application level, and is included as an explanatory variable. (5) Another explanatory variable included is the per capita income, which influences the market demand for forest products. Since per capita income and people's environmental attention are strongly correlated, it therefore reflects people's attention to the environment (Dasgupta et al. 2001).

Based on all these, in the model, the impacts of the application of FSC CoC certification on the global trade of wood products was examined. The dependent variable is the net export value of roundwood, sawnwood, veneer sheet, plywood, particleboard, fibreboard and wood furniture, whereas independent variables include country's capital stock, three types of labor force according to the education level, forestland area, per capita income, the first order lag of dependent variable, and the number of FSC CoC certificates. The model is expressed as follows:

$$\begin{aligned} NET_{ikt} = C_{kt} + \beta_0 NET_{ikt-1} + \beta_1 lab_{1it} + \beta_2 lab_{2it} + \beta_3 lab_{3it} \\ + \beta_4 forest_{it} + \beta_5 ks_{it} + \beta_6 en_{it} + \beta_7 gni_{it} + \varepsilon_{ikt} \end{aligned} \quad (8)$$

where NET_{ikt} means the net export value of country i and product k in year t; NET_{ikt-1} is the first order lag of NET_{ikt}; C_{kt} is a constant for product k in year t; ks_{it} is the capital stock of country i in year t; lab_{1it}, lab_{2it}, lab_{3it} refer to the workforce with high, medium, and low quality respectively in year t; $forest_{it}$ represents the forestland area of country i in year t; en_{it} is the number of FSC CoC certificates of country i in year t; gni_{it} is the per capita income in year t; ε_{ikt} represents the random error term of product K in year t.

In the above model, the estimated coefficient β_6 indicates whether the application of FSC CoC certification has had an impact on the growth of the net trade in wood product and the extent to which this impact has arisen. If the value of β_6 is greater than 0, it indicates that the application does promote the growth of the net trade in wood products.

4.2 Data

The data for forest products were obtained from International Trade Centre Trade Statistics [International Trade Centre UNCTAD/WTO 1994–2015(http://www.intracen.org)]. The data for the forestland area, per capita income and capital stock were retrieved from the World Bank [World Development Indicators, The World Bank(databank.worldbank.org)]. High quality workforce is the number of the population with high education and technic workers (data are from the World Development Indicators, The World Bank), low quality workforce is the number of illiterate people [data are from the UNESCO Institute of Statistics(uis.unesco.org)], and medium quality workforce is the remaining part of the total economic population. The number of FSC CoC certificates comes from the website of FSC [Forest Stewardship Council(http://www.fsc.org)]. Descriptive statistics of the data are presented in Table 6.

5 Results and discussion

Based on a dynamic data panel, the Hausman test was carried out to check for endogenous variables. The result shows that some variables are endogenous, and therefore the generalized moment method (GMM) was applied to estimate Eq. (8). Compared with the difference GMM, the system GMM is more accurate mainly for its smaller standard deviation, although the coefficient values of the two estimations are very close. The estimation results are shown in Table 7, the Abond and Sargan test was carried out on the results and the conclusion is valid.

The effects on the net export of forest products are different based on different factor endowments. The capital stock affects the net export of all wood products significantly, and its effects are positive for sawnwood, veneer sheet and particleboard, while for other products its effects are negative. It means that a larger capital stock is disadvantageous or advantageous to the net export of different types of wood products. The forestland area also has significant effects on the net export of all these products except for veneer sheet, and its effects are positive for all wood products except veneer sheet, fibreboard and wood furniture. High quality labor affects all wood products significantly except for veneer sheet, its effects on furniture and fibreboard are positive, and are negative for all other products. Medium quality labor affects roundwood and veneer sheet negatively, and its effects are significant for roundwood, while it affects other products significantly and positively. Low quality labor affects roundwood, sawnwood, particleboard, fibreboard and wood furniture significantly; its effects are negative for all products except for fibreboard. This result is not in line with the theory of international trade. One of the reasons may be due to the development of other and more important factors, such as restructuring of the forest industries, technological development and movement towards more value-added products, which are the main drivers for the comparative advantage in the different types of trade in wood products of a country (Uusivuori and Tervo 2002; Guan et al. 2018). The per capita income affects roundwood significantly and

Table 6 Descriptive statistics of the data

Variable definition	Variable	Obs	Mean	SD	Min	Max
High quality labor force (thousand)	Lab_1	603	20,668.58	46,641.63	0	435,640
Middle quality labor force (thousand)	Lab_2	603	25,685.78	90,795.66	122	707,806
Low quality labor force (thousand)	Lab_3	603	6729.363	33,392.95	0	293,396
Capital stock (billion USD)	Ks	603	134,152.7	301,464	491.014	2,100,000
Forestland area (square kilometre)	Forest	603	463,489.6	1,268,865	3.5	8,200,000
Per capita income (USD)	Gni	603	20,668.58	46,641.63	0	435,640
The number of FSC CoC certificates	En	603	299.7197	607.0162	0	4114
Net export of roundwood (thousand USD)	Roundwood	603	3889.726	1,263,653	− 7,800,000	7,300,000
Net export of sawnwood (thousand USD)	Sawnwood	603	46,250.18	910,328.1	− 3,400,000	7,300,000
Net export of plywood (thousand USD)	Plywood	603	− 5594.716	41,317.82	− 185,507	155,013
Net export of veneer sheet (thousand USD)	Veneer sheet	603	− 19.53,897	17,498.09	− 102,199	67,288
Net export of particleboard (thousand USD)	Particleboard	603	30,210.25	711,789.8	− 2,400,000	5,700,000
Net export of fibreboard (thousand USD)	Sawnwood	603	10,720.27	205,682.8	− 1,200,000	1,400,000
Net export of wood furniture (thousand USD)	Furniture	603	66,772.85	1,902,108	− 1.10e+07	1.40e+07

positively, while it affects wood furniture, veneer sheet, particleboard and sawnwood significantly and negatively. The negative effect of the per capita income on the net export of veneer sheet, wood furniture, plywood, sawnwood and particleboard is not in line with the theory that demand would increase accordingly to an increase in income. The result seems that the per capita income has structural effects on the forest sector such that richer countries have better developed wood processing industry (Guan et al. 2018). This would be an explanation for the effects of the per capita income obtained from the analysis on the net export of different types of forest products. The first order lag effects of all kinds of forest product are both positive and significant.

The environmental variable has positive effects on the net export of wood furniture, fibreboard, particleboard, plywood and sawnwood, and its effects are significant except for sawnwood, while it has significantly negative effects on the net export of roundwood and veneer sheet. This suggests that the application of FSC CoC certification has brought positive effects on the net trade of sawnwood, plywood, wood furniture, particleboard and fibreboard. The conclusion is consistent with Guan et al. (2018). One possible reason is CoC certification provides an interesting potential business innovation in the value-added wood products sector, and it appears to imply that a company is managing its business well and is showing ethical and environmental responsibility (Gilani et al. 2016). Environmental certification and a corporate focus on exports are two of the more successful initiatives that have been noted with respect to business systems innovations in the forest sector (Wagner and Hansen 2005). This implies certified forest companies are investing in CoC certification as a tool to access new markets where more stringent measures are used to control illegal wood or increase the market share (Chen et al. 2010). Another reason is that countries usually make use of CoC certification to help them comply legally with the legislation in the US or Europe (Lu et al. 2015). These countries have laws like the Lacey Act for the US and the FLEGT for European countries that have the aim to combat illegal logging and promote trade of legal forest products (Wiersum and Elands 2013). As CoC certification is a recognized verification method for identifying the legality of forest products which complies with rules and requirements of the Lacey Act or FLEGT (Li and Chen 2015), exporting countries with CoC certified products gain legal access to these markets (Nguyen and Tran 2011). While the imports of illegal wood into the United States have declined by between 32 and 44% since the Lacey amendments took effect (Environmental Investigation Agency 2015), the FLEGT Action Plan has also achieved its goal of reducing import of illegal logging in Europe since its implementation in 2004 which implies that the certified wood into the United States and Europe has increased (European Commission 2016). However, the result shows that the application of FSC CoC certification has negative effects on the net trade of veneer sheet and roundwood. One possible reason is that countries with good development of FSC CoC certification have a stronger advantage in the production of sawnwood, plywood, wood furniture particleboard and fibreboard, but at the same time, they have obvious disadvantages in the production of roundwood and veneer sheet (Espinoza et al. 2012; Hackett 2013). The application of FSC CoC certification has developed rapidly in 18 countries consisting of China, USA, UK, Germany, Italy, Poland, Japan, Netherlands, Brazil, Spain, France, Canada, Romania, Vietnam,

Table 7 System GMM estimation results

	Furniture	Roundwood	Sawnwood	Veneer sheet	Plywood	Particleboard	Fibreboard
_cons	479,586.2***	−167,828.4***	128,881.7***	15,879.6***	−10,296.2***	116,009.0***	2451.1
	(11.99)	(−5.66)	(3.90)	(10.23)	(−3.43)	(8.91)	(0.28)
Lab1	6.739***	−6.709***	−2.332***	−0.0726	−0.288*	−2.751***	0.364***
	(35.79)	(−25.98)	(−22.65)	(−0.28)	(−2.50)	(−30.90)	(4.10)
Lab2	2.755***	−0.893***	2.484***	−0.155	0.210***	1.632***	2.093***
	(20.40)	(−10.85)	(35.11)	(−0.59)	(7.58)	(42.88)	(13.80)
Lab3	−7.545***	−6.035***	−11.02***	−0.149	−0.0951	−10.89***	1.466***
	(−14.40)	(−6.94)	(−19.82)	(−0.29)	(−0.72)	(−34.14)	(12.68)
Ks	−0.848***	−2.156***	0.729***	0.0336**	−0.0293*	0.415***	−0.373***
	(−37.33)	(−109.72)	(38.12)	(2.71)	(−2.35)	(26.00)	(−21.19)
Forest	−0.408***	0.734***	0.471***	−0.00733	0.0291***	0.433***	−0.101***
	(−11.63)	(30.12)	(26.30)	(−0.88)	(11.29)	(37.77)	(−13.10)
Gni	−20.63***	15.01***	−16.24***	−0.457**	−0.128	−12.38***	0.00810
	(−18.85)	(25.19)	(−34.55)	(−2.74)	(−0.99)	(−38.76)	(0.05)
En	281.1***	−39.06**	12.85	−5.115	16.42**	88.14***	92.72***
	(34.09)	(−2.93)	(1.60)	(−1.45)	(2.91)	(9.71)	(24.03)
L.furniture	0.791***						
	(116.07)						
L.roundwood		0.322***					
		(58.98)					
L.sawnwood			0.720***				
			(167.58)				
L.veneer sheet				0.681***			
				(9.65)			
L.plywood					0.512***		
					(11.85)		
L.particleboard						0.759***	
						(215.32)	
L.fibreboard							0.677***
							(155.91)
N	536	536	536	536	536	536	536
Abond test AR(1) p value	0.06	0.01	0.06	0.0004	0.004	0.03	0.02
Abond test AR(2) p value	0.61	0.41	0.24	0.11	0.08	0.13	0.1
Sargan test p value	0.27	0.2	0.59	0.11	0.12	0.3	0.43

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, *t* statistics value in parentheses

Switzerland, Austria, Belgium and Malaysia, and a great number of the wood products in these countries is certified by the FSC CoC certification. The expansion of the export of these countries means that the amount of certified products is increasing in the world market. The export share of these 18 countries in plywood, particleboard, sawnwood, wood furniture and fibreboard shows an increasing trend in the global market from 2007 to 2016, while the share in veneer sheet and roundwood shows a decreasing trend (Table 8). The results of Table 8 are consistent with the estimation expectation.

6 Limitation of the study

The present study has confirmed the impact of the application of FSC CoC certification on the trade of wood products. However, despite the fact that this paper has reached its objective, this study still has a number of limitations that should be considered in the future. This study is based on the HOV model for analysis. Although, the model provides an illustrative test of the benefits of making one's theoretical and empirical models consistent (James 1993) and can offer an adequate explanation for trade patterns, it is based

Table 8 Export share of the 18 countries in seven types of wood products from 2007 to 2016

Type	2007 (%)	2008 (%)	2009 (%)	2010 (%)	2011 (%)	2012 (%)	2013 (%)	2014 (%)	2015 (%)	2016 (%)
Roundwood	54.1	51.8	49.1	51.2	49.8	50.9	54.2	53.3	53.6	54.0
Particleboard	26.0	26.1	28.0	29.3	32.7	29.2	32.3	31.3	31.0	31.3
Plywood	47.0	45.5	44.4	46.2	47.2	49.1	49.6	51.1	52.7	53.5
Veneer sheet	59.8	57.2	56.5	55.1	54.4	53.1	53.3	55.7	56.9	54.7
Fibreboard	56.6	58.8	57.7	56.9	57.0	58.4	57.8	57.8	58.9	57.9
Sawnwood	42.4	40.0	38.1	40.8	41.0	41.7	43.7	44.1	44.3	45.0
Wood furniture	68.1	68.4	69.7	71.4	72.0	70.7	70.7	71.8	73.2	74.2

Source: International Trade Centre (http://www.intracen.org/)

on over-simplified assumptions. However, the real world has a more complex setting and there is a need to examine the effect of FSC CoC certification in a more complex setting such as in tropical countries. This becomes the first limiting factor of this study. The second limiting factor resides in the choice of the data. The present study has only considered FSC CoC certification and its effect on global trade of wood products. Although FSC CoC accounts for a large proportion of the total number of certificates, CoC certification also includes PEFC standards. However, due to lack of data availability, PEFC has not been considered in this study, which gives room for future research.

7 Conclusion

In this paper, the data of 67 countries from 2007 to 2015 were used to examine the impact of the application of FSC CoC certification on global trade of wood products based on the HOV model. The estimated model has shown that the application has had significant and positive impacts on the net export of particleboard, plywood, wood furniture and fibreboard, while it has had significant and negative impacts on the net export of roundwood. These findings imply that more sawnwood, particleboard, plywood, wood furniture and fibreboard in the global market have been FSC CoC certified than roundwood and veneer sheet in meeting the demand for legal products. Although FSC CoC certification has developed quite well, it has been almost stagnant in recent years, and its application in some countries has even decreased. The application of FSC CoC certification is uneven in the world; its main market is centralized in Europe and Asia, while Africa with relatively rich forest resources possesses a small market (Durst and McKenzie 2006; Fischer et al. 2005). It is necessary to encourage more companies to apply FSC CoC certification for roundwood and veneer sheet.

Funding The author(s) received no financial support for the research, authorship, and/or publication of this article.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Aguilar FX, Cai Z (2010) Conjoint effect of environmental labeling, disclosure of forest of origin and price on consumer preferences for wood products in the US and UK. Ecol Econ 70:308–316

Aguilar FX, Vlosky RP (2007) Consumer willingness to pay price premiums for environmentally certified wood products in the US. For Policy Econ 9:1100–1112

Archer H, Kozak R, Balsillie D (2005) The impact of forest certification labeling and advertising: an exploratory assessment of consumer purchase intent in Canada. For Chron 81:229–244

Baldwin R, Taglioni D (2007) Trade effects of the euro: a comparison of estimators. J Econ Integr 22(4):780–818

Bonnefoi B, Buongiorno J (1990) Comparative advantage of countries in forest-products trade. For Ecol Manag 36:1–17

Bowen HP, Leamer EE, Sveikauskas L (1987) Multicountry, multi-factor tests of the factor abundance theory. Am Econ Rev 77:791–809

Brack D (2014) Promoting legal and sustainable timber: using public procurement policy. Chatham House. http://www.chathamhouse.org/sites/files/chathamhouse/field/field_document/h20140908PromotingLegalSustainableTimberBrackFinal.pdf. Accessed 23 May 2018

Buliga B, Nichiforel L (2019) Voluntary forest certification vs. stringent legal frameworks: Romania as a case study. J Clean Prod 207:329–342

Carodenuto S, Cerutti PO (2014) Forest law enforcement, governance and trade (FLEGT) in cameroon: perceived private sector benefits from VPA implementation. For Policy Econ 48:55–62

Chen J, Innes JL, Tikina A (2010) Private cost-benefits of voluntary forest product certification. Int For Rev 12(1):1–12

Dasgupta S, Mody A, Roy S, Wheeler D (2001) Environmental regulation and development: a cross country empirical analysis. Oxf Dev Stud 29:173–185

Deardorff A (1998) Determinants of bilateral trade: does gravity work in a neoclassical world? In: Frankel JA (ed) The regionalization of the world economy. University of Chicago Press, Chicago, p 21

Durst PB, McKenzie P (2006) Challenges facing certification and Eco-Labelling of forest products in developing countries. Int For Rev 8:193–200

Ebeling J, Yasue M (2009) The effectiveness of market-based conservation in the tropics: forest certification in Ecuador and Bolivia. J Environ Manag 90:1145–1153

Environmental Investigation Agency (2015). The Lacey Act's effectiveness in reducing illegal wood imports. Union of Concerned Scientist. https://www.ucsusa.org/sites/default/files/attach/2015/10/ucs-lacey-report-2015.pdf. Accessed 23 May 2018

Eriksson LO, Sallnas O, Stahl G (2007) Forest certification and Swedish wood supply. For Policy Econ 9:452–463

Espinoza O, Buehlmann U, Smith B (2012) Forest certification and green building standards: overview and use in the U.S. hardwood industry. J Clean Prod 33:30–41

Estevadeordal A, Taylor M (2002) A century of missing trade? Am Econ Rev 92:383–393

European Commission (2016) Evaluation of the EU FLEGT Action Plan (Forest Law Enforcement Governance and Trade) 2004–2014. Evaluation Report Volume 1. https://ec.europa.eu/europeaid/sites/devco/files/report-flegt-evaluation.pdf. Accessed 23 May 2018

Feenstra RC (2004) The Heckscher–Ohlin model. Advanced international trade: theory and evidence. University Press, Princeton, pp 31–63

Feenstra RC, Markusen JR, Rose AK (2001) Using the gravity equation to differentiate among alternative theories of trade. Can J Econ 34:430–447

Fischer C, Aguilar F, Jawahar P, Sedjo R (2005) Forest certification: toward common standards?. Resources for the Future, Washington, pp 71–88

Galati A, Gianguzzi G, Tinervia S, Crescimanno M, Veca DSLM (2017) Motivations, adoption and impact of voluntary environmental certification in the Italian Forest based industry: the case of the FSC standard. For Policy Econ 83:169–176

Gan JB (2005) Forest certification costs and global forest product markets and trade: a general equilibrium analysis. Can J For Res 35:1731–1743

Gilani HR, Kozak RA, Innes JL (2016) The state of innovation in the British Columbia value-added wood products sector: the example of chain of custody certification. Can J For Res 46(8):1067–1075

Guan ZJ, Gong PC (2015) The impacts of international efforts to reduce illegal logging on China's forest products trade flow. China Agric Econ Rev 7:467–483

Guan ZJ, Xu Y (2018) The policy analysis of governing illegal logging: a game theory approach. J Sustain For 37:727–738

Guan ZJ, Shen J, Jia WG (2010) Substituting effects of forest certification in substituting tariff barriers. J Beijing For Univ (Soc Sci) 9:110–113

Guan ZJ, Xu Y, Gong PC, Cao JH (2018) The impact of international efforts to reduce illegal logging on the global trade in wood products. Int Wood Prod J 9:28–38

Hackett R (2013) From government to governance? Forest certification and crisis displacement in Ontario, Canada. J Rural Stud 30:120–129

Heckscher E (1919) The effects of foreign trade on the distribution of income. In: American Economic Association, Translated as chapter 13. Ekonomisk Tidskriff, Stockholm, pp 497–512

Henrya LA, Tysiachnioukb M (2018) The uneven response to global environmental governance: Russia's contentious politics of forest certification. For Policy Econ 90:97–105

James AM (1993) Essays in international trade and the environment: applications of Heckscher–Ohlin and non-traditional trade theories. Doctoral Dissertation 1748, University of New Hampshire, Durham. https://scholars.unh.edu/dissertation/1748. Accessed 23 May 2018

Lawson S, MacFaul L (2010) Illegal logging and related trade: indicators of the global response. chatham house: the Royal Institute of International affairs. https://www.chathamhouse.org/publications/papers/view/109398. Accessed 23 May 2018

Learner E (1984) Sources of international comparative advantage. MIT Press, Massachusetts, pp 103–133

Li JQ, Chen SZ (2015) Empirical analysis on the practical feasibility of timber legality verification work in China. Open J Polit Sci 5:167–179

Liu YZ, Tian ZH (2007) A test on comparative advantages in world and Chinese forest products trade. China Agric Econ Rev 1:28–45

Lu ZY, Eastin I, Ganguly I (2015) The effects of the 2008 lacey act amendment on chinese companies in the forest products industry. CINTRAFOR Newsletter. Summer 1:4–8

Lundmark R (2010) European trade in forest products and fuels. J For Econ 16:235–251

Marasenia TN, Sonb HL, Cockfielda G, Duyb HV, Nghiac TD (2017) The financial benefits of forest certification: case studies of acacia growers and a furniture company in Central Vietnam. Land Use Policy 69:56–63

Maskus KE (1985) A test of the Heckscher–Ohlin–Vanek theorem: the Leontief commonplace. J Int Econ 19:201–212

McDermott CL (2012) Trust, legitimacy and power in forest certification: a case study of the FSC in British Columbia. Geoforum 43:634–644

McDermott CL, Irland LC, Pacheco P (2015) Forest certification and legality initiatives in the lessons for effective and equitable forest governance. For Policy Econ 50:134–142

Miles MP, Covin JG (2000) Environmental marketing: a source of reputational, competitive, and financial advantage. J Bus Ethics 23:299–311

Moroney JR, Walker JM (1966) A regional test of the Heckscher–Ohlin hypothesis. J Polit Econ 74:573–586

Nguyen TQ, Tran HN (2011) How Viet Nam is prepared to meet legal requirements of timber export markets, vol X-44. Tropenbos International Viet Nam, Hue City

Niedziałkowski K, Shkaruba A (2018) Governance and legitimacy of the Forest Stewardship Council certification in the national contexts—a comparative study of Belarus and Poland. For Policy Econ 97:180–188

O'Brien KA, Teisl MF (2004) Eco-information and its effect on consumer values for environmentally certified forest products. J For Econ 10:75–96

Ohlin B (1933) Interregional and international trade. Harvard University Press, Cambridge, pp 105–118

Owari T, Juslin H, Rummukainen A, Yoshimura T (2006) Strategies, functions and benefits of forest certification in wood products marketing: perspectives of Finnish suppliers. For Policy Econ 9:380–391

Panda R, Sethi M, Chaudhuri S (2016) Changing paradigm in trade theories: a review and future research agenda. Indian J Sci Technol 9:1–6

Perera P, Vlosky RP (2006) A history of forest certification. Louisiana forest products development center. http://www.lfpdc.lsu.edu/publications/working_papers/wp71.pdf. Accessed 23 May 2018

Pinto LFG, McDermott C (2013) Equity and forest certification—a case study in Brazil. For Policy Econ 30:23–29

Prestemon J, Buongiorno J (1997) Comparative advantage in forest products trade: a test of the Heckscher–Ohlin–Vanek theorem with interstate data. J For Econ 3:207–228

Qiu YW, Yang G (2007) The impact of green trade barrier on chinese forestry products export and countermeasures. J Int Trade 5:23–28

Riera P, Aranda L, Mavsar R (2007) Efficiency and equity of forest policies: a graphic analysis using the partial equilibrium framework. For Policy Econ 9:852–861

Schwarzbauer P, Rametsteiner E (2001) The impact of SFM-certification on forest product markets in Western Europe an analysis using a forest sector simulation model. For Policy Econ 2:241–256

Sen S (2010) International trade theory and policy: a review of the literature. Levy Economics Institute Working Papers Series No. 635. https://ssrn.com/abstract=1713843 or http://dx.doi.org/10.2139/ssrn.1713843. Accessed 23 May 2018

Styles D, Schoenberger H, Martos JLG (2012) Environmental improvement of product supply chains: a review of European retailers' performance. Resour Conserv Recycl 65:57–78
Toit LD, Fourie J, Trew D (2010) The sources of comparative advantage in tourism. Working Papers 01/2010, Stellenbosch University, Department of Economics. https://ideas.repec.org/p/sza/wpaper/wpapers100.html. Accessed 23 May 2018
Tricallotis M, Gunningham N, Kanowski P (2018) The impacts of forest certification for Chilean forestry businesses. For Policy Econ 92:82–91
Upton C, Bass S (1996) The forest certification handbook. St. Lucie Press, Florida, pp 60–88
Uusivuori J, Tervo M (2002) Comparative advantage and forest endowment in forest products trade: evidence from panel data of OECD-countries. J For Econ 8:53–75
Vanek J (1963) The natural resource content of united states foreign trade. MIT Press, Massachusetts, pp 78–98
Vanek J (1968) The factor proportions theory: the N-factors case. Kyklos 21:749–756
Verter N (2016) The Heckscher–Ohlin model and the performance of cocoa products in Nigeria. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 64:2161–2172
Viana V, Gholz H, Donovan R (1996) Certification of forest products: issues and perspectives. Island Press, Washington, DC, pp 48–63
Vidal N, Kozak R, Cohen D (2005) Chain of custody certification: an assessment of the North American solid wood sector. For Policy Econ 7:345–355
Vogt KA, Larson BC, Fanzeres A (2000) Forest certification: roots, issues, challenges, and benefits. CRP Press, Connecticut, pp 33–47
Wagner E, Hansen E (2005) Innovation in large versus small companies: insights from the U.S. wood products industry. Manag Decis 43(6):837–850
Wiersum KF, Elands BHM (2013) Opinions on legality principles considered in the FLEGT/VPA policy in Ghana and Indonesia. For Policy Econ 32:14–22
Yamamoto Y, Takeuchi K, Shinkuma T (2014) Is there a price premium for certified wood? Empirical evidence from log auction data in Japan. For Policy Econ 38:168–172