Asia-Pacific Journal of Regional Science (2021) 5:477–511
https://doi.org/10.1007/s41685-020-00189-x

ARTICLE

Gravity analysis of trade for environmental goods focusing on bilateral tariff rates and regional integration

Atsuko Matsumura[1]

Received: 14 September 2020 / Accepted: 27 December 2020 / Published online: 1 March 2021

Abstract
The importance of trade liberalization of environmental goods has been widely recognized since the 2001 Doha Ministerial Declaration of the World Trade Organization. This paper investigates the determinants of bilateral trade for ten environmental goods used in renewable energy production and monitoring environmental conditions, based on the classification of the Asia–Pacific Economic Cooperation (APEC). This study contributes to the fields of trade and environmental protection by rigorously assessing the effects of tariff reduction and regional integration on the trade of environmental goods, using data of 73 countries for 4 years from 2013 to 2016. The results of three types of analyses with the gravity model show robust effects of bilateral tariff rates on three goods, HS850300 (parts of renewable energy electricity generating sets), HS902610 (instruments for measuring air quality), and HS902620 (instruments for measuring pressure). Furthermore, the results show the robust effect of regional integration for the European Union on two goods, for the APEC on four goods, and for East and South-East Asia on three goods. In addition, by examining the intra-industry trade index of the goods having regional trade effect, it is found that the main developed countries and some emerging countries tend to have high indices based on either product differentiation of final goods or production fragmentation of parts and components within each region. These results suggest that reducing tariff rates on more environmental goods through policy decisions and strengthened regional networks will accelerate the trade and proliferation of environmental goods considered beneficial for environmental protection.

Keywords Environmental goods · International trade · Gravity model · Tariff rate · Regional integration · Environmental protection

✉ Atsuko Matsumura
atsukom@tiu.ac.jp

1 Department of Economics, Tokyo International University, Kawagoe-City, Saitama, Japan

1 Introduction

This paper investigates the determinants of bilateral trade of environmental goods (EGs) including bilateral tariff rates and regional integration. EGs are useful for protecting the environment, and the importance of trade liberalization of the EGs has been widely recognized since the 2001 Doha Ministerial Declaration of World Trade Organization (WTO). This declaration initiated the reduction or elimination of tariff and non-tariff barriers to trade in environmental goods and services (EGSs).

In 2011, the WTO report TN/TE/20 was released with the Annex II.A, which contains a list of the EGs based on the Harmonized System (HS) classification at the six-digit level. In 2012, the Asia–Pacific Economic Cooperation (APEC) put together a list of 54 EGs and affirmed their commitment to reduce applied tariff rates to 5% or less by the end of 2015. This reduction of tariffs is specified in Annex C of the 2012 Vladivostok Declaration. Then on July 8, 2014 at the WTO, 14 members, including China, the European Union (EU) and the United States, launched plurilateral negotiations on trade liberalization for EGs. Presently, there are 46 countries engaged in the negotiations.[1]

The potential impact of trade liberalization and trade increase of EGs is easily illustrated. This trade liberalization would lead to import demand expansion through import price decrease resulting from tariff reduction, especially in fast-growing developing economies which have comparatively high tariff rates on these goods. Importing EGs at a lower price makes it possible to access climate-friendly goods with clean energy technologies, which could have a substantial effect on climate change mitigation. Especially for the renewable energy sector, cost has been the principal obstacle to the deployment of renewable energy-based electricity generation in developing countries; the reduction or removal of these tariffs contributes significantly to improving access to these goods. Access to more energy-efficient technologies at a lower cost may be particularly important for industries that must comply with environmental policies, which place the burden of emission reductions on the emitters.[2]

The effects of trade liberalization on climate change mitigation can be seen not only on the demand side of the importing countries, but also on the production side of those goods in the importing countries. Increased imports of EGs give producers in the importing countries the opportunity to learn and benefit from technological advances, and allows larger markets for EGs leading to profits from economies of scale by production increase. There are numerous examples that indicate that trade liberalization of EGs increases local capabilities for innovation and adaptation of domestic technology rather than simply fostering dependence on the transfer of foreign technology.[3]

[1] See Matsumura (2016a), (2016b), (2019) for details on the trade liberalization of environmental goods.

[2] See WTO (2009), UNEP (2012), and UNEP (2014) for details.

[3] WTO (2009) shows the example of Ghana where the reduction of certain import tariffs has encouraged the adoption of energy-efficient lighting.

Trade increase in EGs affects producers in the exporting countries as well. The production of EGs has the following characteristics. First, at the initial stage of production, sunk costs for research and development are enormous, and second, the degree of product differentiation can be large depending on the producers. Consequently, many EGs are produced in monopolistic competitive industries with monopolistic power for each variety which is produced with scale economies. Following trade liberalization of EGs in the importing countries, production increase of exporting countries having comparative advantage leads to average cost decrease and profit increase based on economies of scale, which induces the entry of new firms with new varieties.

The trade benefit for users on the demand side realized by trade liberalization is the expansion of choices among the varieties with lower prices as a result of increased competition among producers of both exporting and importing countries. Accordingly, these effects on the monopolistic competitive environmental industries will lead to an increase in the worldwide deployment of EGs, which will possibly induce successful environmental protection.

For this study, seven goods which contribute to renewable energy production are selected, due to the fact that electricity from renewable energy sources is increasing in every region in the world.[4] However, the photovoltaic cells sector is not included in this study, as the determinants for this sector were previously examined in Matsumura (2016b) and Matsumura (2019). In addition to EGs related to renewable energy production, three EGs of precision instruments which contribute to monitoring environmental conditions are selected. Those ten EGs are shown in Table 1, under HS 2012 classification at the six-digit level.

The estimation model is based on the fixed effect approach of the gravity model with importer and exporter dummy variables. This model is useful for examining the effect of bilateral tariff rates and other proxies of trade costs, such as distance and dummy variables of common language and regional integration. Bilateral tariff rates depend on trade relationships developed through regional trade agreements (RTAs), and thus it is important to examine the effect of RTAs along with the effect of bilateral tariff rates such as most-favored nation (MFN) tariffs and tariffs of generalized system of preferences under WTO. Following Hayakawa (2013), the present paper assumes exporters use the lowest tariff rates although multiple tariff schemes are available in most country pairs for each RTA.

The estimation results are rigorously investigated to show cases in which the coefficients of three estimation methods are significant for each of the ten EGs examined in this study. In addition to examining the effect of tariff rates, other important determinants of trade including regional integration are investigated in detail. For the EGs with a significant effect of regional integration, the intra-industry index is introduced to clarify the trade pattern of each country within each region.

The paper is structured as follows. In the next section, there is a brief review of the literature on the effects of tariffs in the gravity model and the determinants of trade in EGs. Section 3 describes the theoretical foundation of the gravity model

[4] See Matsumura (2019) for details.

Table 1 List of environmental goods included in this study

HS2012 number	HS code description	Environmental benefit
841290	Engine and motor parts	Integral components to wind turbines (wind turbines and hubs)
850231	Wind-powered electric generating sets and equipment	Electricity generation from renewable resources
850239	Electric generating sets and rotary converters	Electricity generation from renewable resources
	Biogas generating sets; gas generator	
850300	Parts suitable for use with the machines of heading 8502	Parts for electricity generation from renewable resource
850490	Parts for electrical transformers, static converters and inductors	Used to convert DC (direct current) from renewable energy generating sets into conventional AC (alternative current) electricity
901380	Solar heliostats (optical devices, appliances and instruments)	Heliostats orient mirrors in concentrated solar power (CSP) systems to reflect sunlight on to a CSP receiver
901390	Parts of solar heliostats (optical devices, appliances and instruments)	Heliostats orient mirrors in concentrated solar power (CSP) systems to reflect sunlight on to a CSP receiver
902610	Instruments for measuring or checking the flow, level, pressure or other variables of liquids or gases	Used to measure, record, analyze and assess environmental samples or environmental influences, such as air quality monitors and dust emissions monitors
902620	Instruments for measuring or checking the pressure for power plant	Manometers used in power plants, water delivery systems, and other application such as monitoring indoor air, which have important environmental applications
902690	Parts for articles of subheading 9026	Used to measure, record, analyze and assess environmental samples or environmental influences

Source: APEC (2012)

for the disaggregated goods, the specification of the estimating model, and the data. Section 4 presents the estimation results for the determinants of trade in each EG, a comparison among the results of the ten goods, and the trade pattern of each country in each good having the robust effect of regional integration. Section 5 concludes.

2 Related literature

While the present study examines the determinants of bilateral trade in disaggregated EGs, Disdier et al. (2009) examine the determinants of bilateral trade for each item included in cultural goods. In Disdier et al. (2009), the effect of common language, colonial links, and the proximate cultural tastes on bilateral trade in cultural goods are examined carefully based on the gravity equation with importer and exporter fixed effects interacting with year dummies. Although they emphasize the importance of the liberalization of trade of cultural goods in future multilateral trade negotiations, they do not introduce bilateral tariffs in the estimation.

Other papers reviewed here introduce bilateral tariff rates implicitly in the gravity model. Hayakawa (2013) examines the effects of omitting bilateral tariff rates from gravity equations for aggregated manufacturing goods. Hayakawa (2013) concludes that the effect of omitting bilateral tariff rates seems negligible in regard to omitted-variable bias, and RTA dummy variables are not an appropriate substitute for tariff rates.

Disdier et al. (2015) investigate impacts of tariff cuts on trade margins for the exports from 18 emerging countries to 25 main importing countries. Based on the model with the first-differences trade data between 1996 and 2006 with country-pair fixed effects, Disdier et al. (2015) clarify a positive effect of tariff cuts at both extensive and intensive trade margins, though the effects are relatively modest. In addition, based on the basic gravity model, the coefficients of tariff rates are negative and significant in various cases for extensive and intensive margins.

In papers which examine the determinants of the trade of EGs, the following papers show the estimation results according to their specific purposes. Jomit (2014) examines the determinants of exports of EGs from India to 58 countries for the period between 1991 and 2011, showing that the coefficient of GDP of the importing countries, the common colonizer, and membership in bilateral trade agreements are positively significant. Cantore et al. (2018) show that the trade of EGs based on OECD classification depends on GDP, transaction costs, and uncertainty using trade data from 1999 to 2014 across 71 countries. In an analysis focusing on the renewable energy industries including solar photovoltaic cells and wind power, Kuik et al. (2018) show the effectiveness of demand-pull policies on trade increase.

Related to research on environmental protection estimated by trade change, Nunez-Rocha and Martinez-Zarzoso (2018) estimate the effects of two international agreements (Rotterdam Convention and Stockholm Convention) on environmental protection which reduce trade in hazardous chemicals or persistent organic pollutants. The results from the gravity model show that when the exporters ratify the Rotterdam Convention a significant reduction of imports of non-OECD countries from OECD countries in hazardous chemicals is observed. In the case of the Stockholm Convention, a reduction in persistent organic pollutants is observed.

Matsumura (2016a) examines the determinants of trade structure in EGs focusing on regional trade integration, by investigating the trade of EGs in the APEC list for each group of HS84, HS85, and HS90, from 2009 to 2012.[5] Based on the gravity model, the trade share of parts and components is shown as the driving force of trade increase in the APEC region for the EGs in the HS84 and HS90 groups, and in Japan-ASEAN FTA for those in the HS85 group, because trade increase is due to the proliferation of complex supply chain networks in EGs. On the other hand, for EU countries, trade is higher for the two countries with higher ratio of final goods than the two countries with higher ratio of parts and components.

Matsumura (2016b) investigates the effect of bilateral tariff rates for specific renewable energy-related products, using the example of the photovoltaic cells sector, which is classified in HS at the nine-digit level under the heading of HS854140. This analysis focuses on the period 2000–2004, a period with tariff reduction and trade increase for photovoltaic cells. The study clarifies the significant effect of bilateral tariff rates on trade using the fixed effect approach of the gravity model. However, a later study (Matsumura 2019) shows that the effect of tariffs on trade depends on the goods being traded. With regards to the effect of regional integration, this paper shows that the trade of wind-powered electric generating sets and equipment is active among EU countries and the trade of photovoltaic cells is active among APEC countries. This type of estimation includes bilateral tariff rates influenced by all the existing RTAs, so that both the effects of RTAs and the effect of bilateral tariff rates are taken into consideration. The present study examining the trade determinants of ten EGs extends Matsumura (2019).

3 Estimating model

3.1 Theoretical foundation of gravity model for disaggregated EGs

The theoretical foundation of the gravity model is based on the trade theory of monopolistic competition with constant elasticity of substitution (CES) expenditure function and iceberg trade costs.[6] Increasing returns to scale is assumed in producing differentiated varieties of the good in each country and they are shipped to all countries with an iceberg trade cost in which the trade costs are proportional to the volume shipped.

[5] This analysis includes 43 countries with 17 countries in APEC, 21 countries in EU, and 5 countries such as Brazil, India, South Africa, Switzerland, and Turkey.

[6] A detailed theoretical explanation is given in Anderson (2010), De Benedictis and Taglioni (2011), and Feenstra (2016). The method to derive the estimation equation from the theory is given by Disdier et al. (2009), Hayakawa (2013), Head and Mayer (2014) and Tanaka (2015).

The theoretical foundation of the gravity model is derived in the following way. According to Anderson (2010) in the "frictionless gravity lessons," a frictionless world implies that each good has the same price everywhere, and a homogeneous world implies that economic agents everywhere might be predicted to purchase goods in the same proportions when faced with the same prices. Under the assumption of a frictionless and homogeneous world, the proportion of spending by destination country *j* on goods from country *i* in the sum of purchases from all origins is equal to the global proportion of spending on goods from country *i*.

$$\frac{X_{ij}}{E_j} = \frac{Y_i}{Y}, \tag{1}$$

where X_{ij} is the import value of country *j* from country *i*, E_j is the sum of purchases in country *j* from all origin countries, Y_i is the total sales by origin country *i*, and *Y* is world spending. On the other hand, as the observed trade value X_{ij} is affected by frictions in the real world along with random influences, the ratio of observed trade value to predicted frictionless trade, Y_iE_j/Y can be explained by various proxies for trade costs for frictions by the empirical gravity models.

For the analysis of gravity model for each disaggregated EGs, this relationship can be extended for the application to disaggregated goods, indexed by *k*.

$$X_{ij}^k = Y_i^k E_j^k / Y^k = s_i^k b_j^k Y^k, \tag{2}$$

where $s_i^k = Y_i^K / Y^K$ is country *i*'' s share of the world's sales of goods *k* and $b_j^k = E_j^k / Y^K$ is country j's share of the world spending on good *k*, and Y^k is world sales of good *k*.

According to Anderson and van Wincoop (2003), the theory-based gravity model can be derived in the following way. By specifying the demand structure by CES function, exports from country *i* to country *j* in product *k*, X_{ij}^k is given by

$$X_{ij}^k = \left(\frac{p_{ij}^k}{P_j^k}\right)^{1-\sigma^k} E_j^k, \tag{3}$$

where σ^k is the elasticity of substitution among differentiated varieties of the goods, p_{ij}^k is the price charged by country *i* for exports to country *j*, and P_j^k is the CES price index, E_j^k is expenditure in country *i* for good *k*. The CES price index is given by

$$P_j^k = \left[\sum_i (p_{ij}^k)^{1-\sigma^k}\right]^{1/(1-\sigma^k)}. \tag{4}$$

As iceberg trade costs are assumed, p_{ij}^k can be written as $p_i^k t_{ij}^k$, using supply price received by producers in country *i*, p_i^k and trade costs, t_{ij}^k, where $t_{ij}^k - 1$ is ad-valorem tax equivalent of trade costs.

Together with the market-clearing conditions, the gravity equation system for good *k* can be shown as:

$$X_{ij}^{k} = \frac{E_j^k Y_i^k}{Y^k} \left[\frac{t_{ij}^k}{P_j^k \Pi_i^k} \right]^{1-\sigma^k}, \tag{5}$$

$$(\Pi_i^k)^{1-\sigma^k} = \sum_j \left[\frac{t_{ij}^k}{P_j^k} \right]^{1-\sigma^k} \frac{E_j^k}{Y^k}, \tag{6}$$

$$(P_j^k)^{1-\sigma^k} = \sum_i \left[\frac{t_{ij}^k}{\Pi_i^k} \right]^{1-\sigma^k} \frac{Y_i^k}{Y^k}, \tag{7}$$

where Π_i^k and P_j^k are outward and inward multilateral resistance, respectively, and this system shows that bilateral trade depends on relative trade barriers, with these key variables. It suggests that the trade flow of good *k* from country *i* to country *j* is increased by high trade costs from other suppliers to *j* as captured by inward multilateral resistance, and that high resistance to shipments from country *i* to markets other than country *j*, captured in outward multilateral resistance, increases trade from country *i* to country *j*.

3.2 Econometric specification and data

Based on the theoretical foundation presented in the previous section, the determinants of the trade of each of the ten disaggregated EGs are examined by fixed effect approach of the gravity model, using importer and exporter dummy variables.

The specification of the fixed effect approach of the gravity model in this study can be shown as follows:

$$\ln X_{ijt} = \theta + \mu_i fe_i + \lambda_j fe_j + \delta_1 lnDIST_{ij} + \beta_1 \ln\left(1 + TAR_{ijt}\right) + \beta_2 CL_{ij} + \beta_3 AP_{ij} + \beta_6 EU_{ij} + u_{ijt}, \tag{8}$$

where X_{ijt} denotes the value of exports from country *i* to partner *j in year t*, fe_i is country dummy variable,fe_j is the partner country dummy variable, and u_{ijt} is a stochastic error. $DIST_{ij}$ is the distance between capitals of the pair countries, TAR_{ijt} is bilateral tariff rates of the country *j* from country *i in year t*. CL_{ij} is the dummy variable for common language, AP_{ij} is the dummy variable for the membership of APEC, and EU_{ij} is the dummy variable for the membership of EU.

The bilateral tariff rates reflected by RTAs are introduced in the estimating equation to take into account the trade cost from the point of view of trade policy. For the proxies used to examine the effects of other trade costs, some dummy variables are introduced in the estimating equation. The dummy variable for common language takes one for two countries with a common official language and zero in other cases, the regional dummy variable of APEC takes one for two countries belonging to APEC and zero otherwise, and the regional dummy variable of EU takes one for two countries belonging to EU and zero otherwise.

According to Redding and Venables (2004), one is added to all trade flows before taking logarithms, as zeroes are genuine zeroes rather than missing values based on the accuracy of the bilateral trade flows data. Importer and exporter fixed effects are included in all the regressions in the form of country dummies. As Disdier et al. (2009) clarify, those fixed effects incorporate the size effects, but also the price and number of varieties in the exporting country and the size of demand and the price index of the importing country.

To examine the trade network in East and South-East Asia instead of APEC, the dummy variable of the countries and regions of East and South-East Asia, including so-called ASEAN plus 3 countries (Japan, Korea, and China), and the regions of Hong Kong and Taiwan are introduced. For ASEAN countries, 8 countries are included except for Brunei and Laos.[7] This dummy variable *AS3* (ASEAN + 3) takes 1 for two countries among these countries and regions, and 0 otherwise. The gravity equation is altered as shown by the following equation:

$$\ln X_{ijt} = \theta + \mu_i fe_i + \lambda_j fe_j + \delta_1 lnDIST_{ij} + \beta_1 \ln\left(1 + TAR_{ijt}\right) + \beta_2 CL_{ij} + \beta_3 AS3_{ij} + \beta_6 EU_{ij} + u_{ijt}. \tag{9}$$

The four years from 2013 to 2016 are selected for the estimation period based on the panel data. In addition to pooled ordinary least squares (OLS) and random-effect model, the Poisson pseudo-maximum-likelihood (PPML) method proposed by Silva and Tenreyro (2006) is also applied in the analysis, for a robustness check. This method avoids the inconsistency occurring when the gravity equation is estimated using a log–log functional form, in the presence of heteroscedasticity and zero trade flows. In this case, the left-hand side term is taken in levels. In addition, according to Fally (2015), the estimation of gravity model with PPML and exporter and importer fixed effects is consistent with a structural approach by satisfying restrictions on exporter and importer multilateral resistance terms. The random-effect model is selected because the time invariant distance variable is included in the estimation model.

As described in Sect. 1, ten EGs are selected from the APEC list of EGs based on the six-digit level of harmonized system HS2012. Table 1 presents the characteristics of these ten EGs and the environmental benefits for each. The first seven items in the table are EGs for renewable energy production. Specifically, HS841290 is the parts and components including the wind turbines and hubs, HS850231 includes wind-powered electric generating sets and equipment, HS850239 includes electric generating sets and rotary converter for production of renewable energy, and HS850300 includes the parts and components for those goods. In addition, HS850490 includes important parts and components for electrical transformers, static converters and inductors. HS901380 includes heliostats orient mirrors in concentrated solar power systems, and HS901390 includes parts and components of HS901380. These seven items are the EGs for renewable energy production included in the APEC list.

The last three items, belonging to the HS90 group of precision machinery, are the principal instruments for measuring or checking the environmental conditions.

[7] Cambodia and Myanmar are included only as importing countries in this analysis.

Fig. 1 Applied most-favored-nation (MFN) tariff rates for 10 EGs for selected countries (2013: blue, 2014: red, 2015: green, 2016: purple). **a** Applied MFN tariff rates for selected countries, HS841290 (%). **b** Applied MFN tariff rates for selected countries, HS850231 (%). **c** Applied MFN tariff rates for selected countries, HS850239 (%). **d** Applied MFN tariff rates for selected countries, HS850300 (%). **e** Applied MFN tariff rates for selected countries, HS850490 (%). **f** Applied MFN tariff rates for selected countries, HS901380 (%). **g** Applied MFN tariff rates for selected countries, HS901390 (%). **h** Applied MFN tariff rates for selected countries, HS902610 (%). **i** Applied MFN tariff rates for selected countries, HS902620 (%). **j** Applied MFN tariff rates for selected countries, HS902690(%) (color figure online) ▶

HS902610 is the instruments for measuring or checking the flow, level, pressure or other variables of liquids or gases to check environmental samples or environmental influences such as air quality monitors and dust emissions monitors. HS902620 is the instruments for measuring or checking pressure, such as manometers used in power plants, water delivery systems, and other applications such as monitoring indoor air, which have important environmental applications. HS902690 is for parts for articles of subheading 9026 to measure, record, analyze and assess environmental influences.

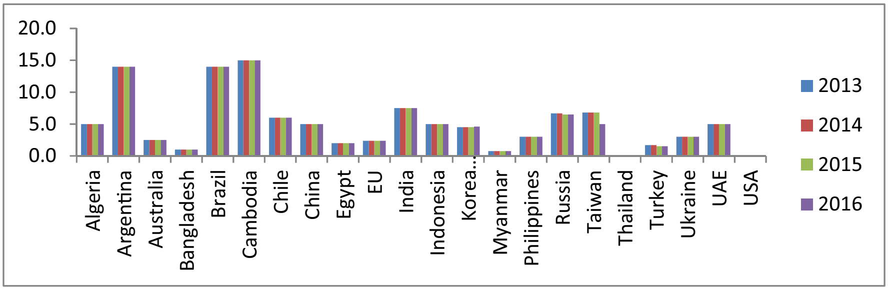
The sources of the data used for the estimation are described briefly as follows. The bilateral trade values of each of the ten EG sectors (in US dollars) for 73 trading countries are taken from the Global Trade Atlas online database, providing customs trade data reported by the government of each country and region. This database is available at Business Database Corner of the Japan External Trade Organization, JETRO. The data of bilateral distance between capitals of the pair countries and the data for common language are from the CEPII (Centre d'Etude Prospectives d'Informations Internationales) database.

The data sources of bilateral tariffs reflected by RTAs are the WTO Tariff Download Facility and FedEx Trade Network—World Tariff Account Information. Together with the information from the WTO website for "Regional Trade Agreements Database" for each country, the analysis uses the preferential tariff rate of each RTA for each country. The use of these data in this paper is based on the assumption that exporters use the lowest tariff rates, although multiple tariff schemes are available in most country pairs.

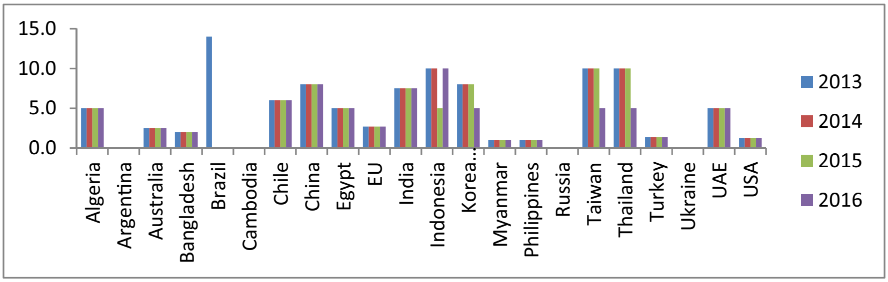
Table 6 in Appendix 1 shows the 73 countries included in the analysis. Developed and newly industrialized countries belonging to APEC and EU, and another seven countries are introduced in the estimation as exporting and importing countries. Eighteen developing countries are included as the importing countries, as these countries have no significant exports for those EGs.

The descriptive statistics of each variable by good are shown in the Table 7 in Appendix 2. Figure 1 presents applied most-favored-nation (MFN) tariff rates of the 22 selected countries, for each HS six-digit number, respectively. These tariff rates are taken from the database for bilateral tariff rates constructed for the present study, to show the trend of tariff rates levied by the representative countries. Together with the information on bilateral tariff rates in the descriptive statistics, it is shown that sectors of HS902610 and HS902690 have relatively low bilateral tariff rates because of the tariff elimination policies in many economically influential countries. On the other hand, the sectors of the parts and components,

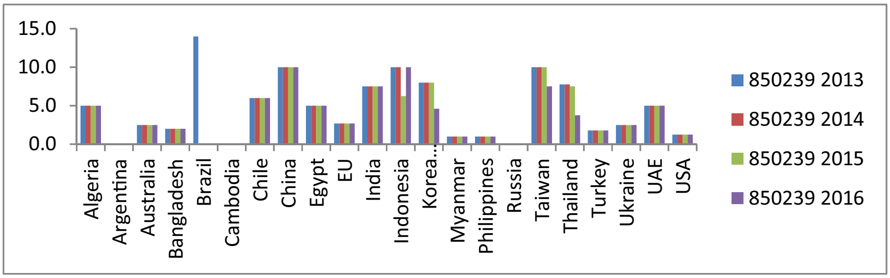
a)Applied MFN Tariff Rates for Selected Countries, HS841290 (%)



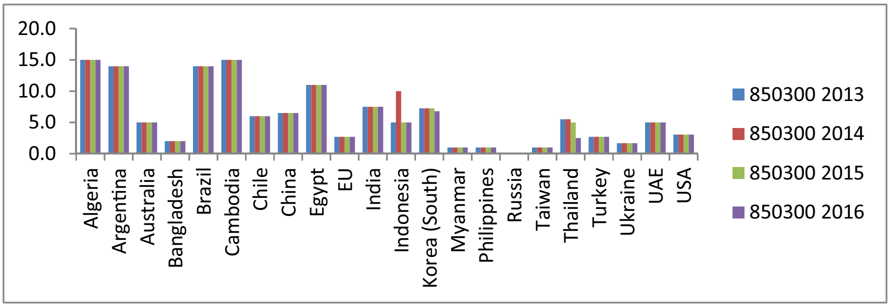
b)Applied MFN Tariff Rates for Selected Countries, HS850231 (%)



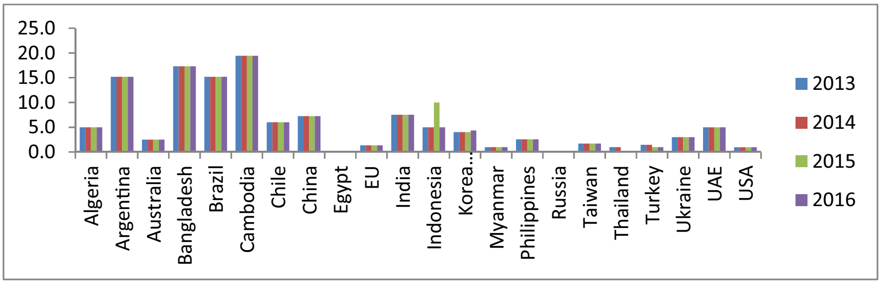
c)Applied MFN tariff rates for selected countries, HS850239 (%)



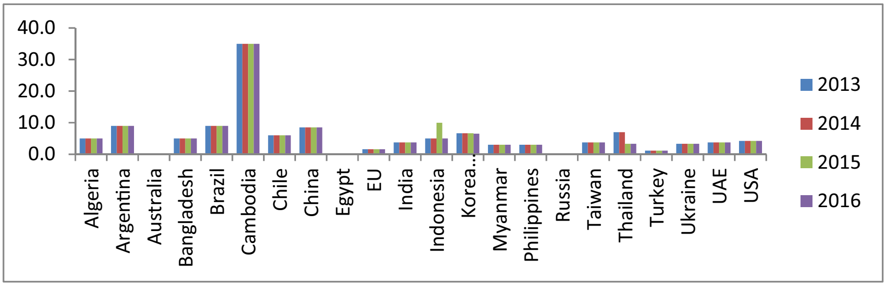
d)Applied MFN tariff rates for selected countries, HS850300 (%)



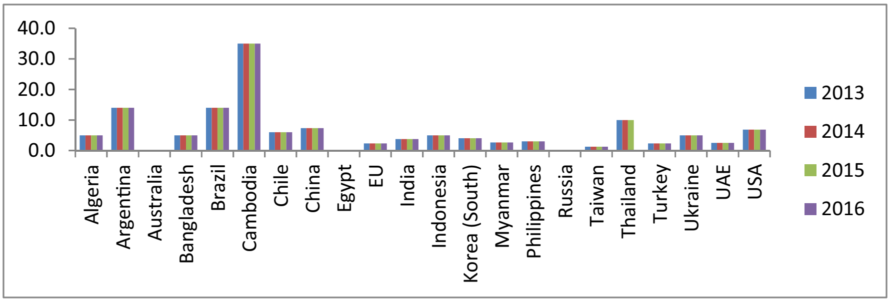
e)Applied MFN Tariff Rates for Selected Countries, HS850490 (%)



f) Applied MFN Tariff Rates for Selected Countries, HS901380 (%)



g)Applied MFN Tariff Rates for Selected Countries, HS901390 (%)



h) Applied MFN Tariff Rates for Selected Countries, HS902610 (%)

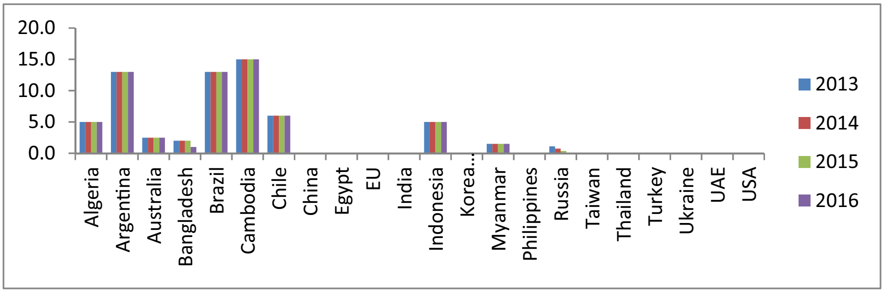
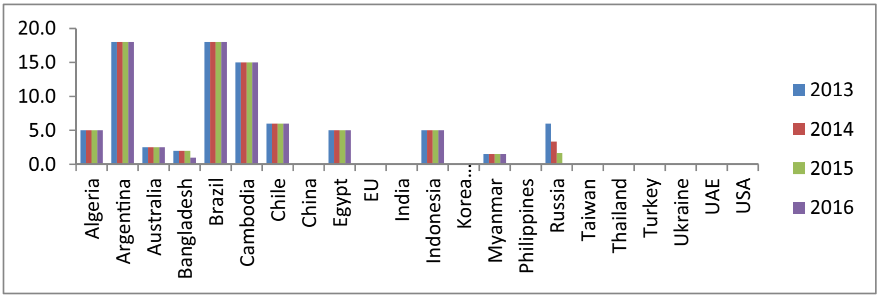


Fig. 1 (continued)

i)Applied MFN Tariff Rates for Selected Countries, HS902620 (%)



j)Applied MFN Tariff Rates for Selected Countries, HS902690(%)

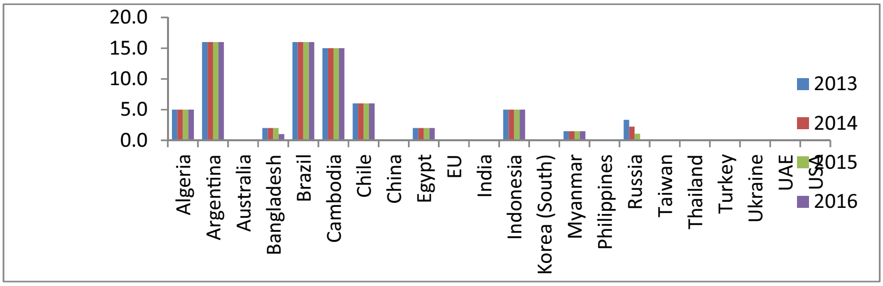


Fig. 1 (continued)

HS841290, HS850300, HS850490, and HS901390, and the final goods sector HS901380 have high bilateral tariff rates because of the relatively high rates in the developing countries and also in the main developed or emerging countries. For HS850231 and HS850239, the developing countries have relatively low bilateral tariff rates. Most cases of MFN tariff rates shown in this figure seem to be invariant during 2013 and 2016. As the preferential tariff rates based on each RTA and other preferential agreements are used in the panel analysis, the actual tariff rates of ten EGs during 2013 and 2016 for each pair countries are more variable than the sample of MFN tariff rates for 22 countries shown in Fig. 1.

In some APEC member countries and regions, applied MFN tariff rates were reduced to less than 5% in 2015 or 2016 following the commitment of APEC. For example, Thailand and Taiwan reduced tariff rates of HS841290, HS850231, HS850239, and HS901380 in 2015 or 2016.

4 Estimation results

This section presents the estimation results for Eq. (8) and Eq. (9). Importer and exporter fixed effects are included in all the regressions for the three estimation methods: pooled OLS, random-effect model, and PPML.

4.1 Effects of bilateral tariff rates and RTAs

Table 2 shows the estimation results of three methods, pooled OLS, random-Effect, and PPML, for each of the ten EGs. Focusing on the effects of the bilateral tariff rates combined with the effects of RTAs, the results for each EG show differences, suggesting the existence of good-specific characteristics. For HS850300 (parts and components for electricity generation from renewable sources), the coefficients of bilateral tariff rates are significant at the 1% level in all three estimation methods ranging between − 0.308 and − 0.413.

Similar results are shown for two EGs belonging to the precision machinery sectors, HS902620 and HS902610. For HS902620 (manometers for monitoring environmental conditions), the coefficients are significant at the 1% level in pooled OLS and PPML and significant at the 5% level in random-effect model ranging between − 0.175 and − 0.242. For HS902610 (instruments for monitoring air quality and other environmental conditions), the coefficients are significant at the 1% level in pooled OLS and random-effect Model and significant at the 10% level in PPML ranging between − 0.117 and − 0.434. On the other hand, for the sector of parts and components for these two EGs, HS902690, the coefficients are significant at the 1% level in pooled OLS at − 0.283 and significant at the 5% level in random-effect model at − 0.259, but the coefficient is not significant in PPML.

Accordingly, the effects of bilateral tariff rates can be considered robust for three out of ten EGs. For those EGs with significant coefficients of tariff rates in all the three estimation models, the tariff elasticity of demand for imports ranges between 0.117 and 0.434 which is on a similar scale as the results in Disdier et al. (2015) for the exports of emerging countries.

4.2 Effects of distance and common language

The effects of other proxies for trade costs such as distance and dummy variable for common language are shown in Table 2. Distance has a negative and significant effect on trade flows of all the ten goods in all the three estimation methods. The coefficients are significant at the 1% level, ranging between − 0.644 for HS850231 (wind-powered electric generating sets and equipment) and − 2.380 for HS850300 (parts for electricity generation from renewable resources) in the pooled OLS; between − 0.639 for HS850231 and − 2.394 for HS850300 in random-effect model; and between − 0.477 for HS902620 (manometers for monitoring environmental conditions) and − 1.092 for HS850231 in PPML. For nine goods out of the ten, the estimated coefficients of PPML are smaller than those of pooled OLS. According to Head and Mayer (2914) and Fally (2015), this can be explained by a non-linear effect of distance, with a stronger effect on small trade flows captured by polled OLS and a weaker effect on large trade flows captured by PPML. Despite the coefficients varying among the goods and estimation methods, these results clearly demonstrate the impact of distance between two countries.

The effects of a common official language between two countries on trade flows are examined by the dummy variable shown as DCL in Table 2. The coefficients of DCL are positive and significant at the 1% level, for seven goods out

Table 2 Estimation results for gravity equation (8)

	Pooled OLS HS841290	RE model	*Xij*, PPML	Pooled OLS HS850231	RE model	*Xij*, PPML	Pooled OLS HS850239	RE model	*Xij*, PPML
	Integral components to wind turbines			Wind-powered electric generating sets			Electric generating sets, rotary convertors		
Constant	30.135***	30.131***	20.505***	8.809***	8.821***	23.126***	20.465***	20.319***	19.608***
	(0.665)	(1.132)	(0.588)	(0.649)	(0.991)	(2.166)	(0.781)	(1.210)	(1.167)
ln(*Tariffij* + 1)	−0.006	0.038	− 0.177**	− 0.039	− 0.093	0.149	− 0.386***	− 0.148	0.035
	(0.064)	(0.098)	(0.075)	(0.068)	(0.090)	(0.260)	(0.081)	(0.112)	(0.115)
ln(*DISTij*)	−1.975***	− 1.981***	− 0.663***	− 0.644***	− 0.639***	− 1.092***	− 1.541***	− 1.561***	− 0.936***
	(0.053)	(0.093)	(0.045)	(0.053)	(0.082)	(0.192)	(0.063)	(0.100)	(0.089)
DCLij	1.033***	1.035***	0.062	0.498***	0.499***	0.405	0.900***	0.914***	− 0.478**
	(0.121)	(0.206)	(0.091)	(0.122)	(0.184)	(0.304)	(0.156)	(0.242)	(0.233)
DAPECij	0.490***	0.493**	0.677***	− 0.020	− 0.029	− 0.771	0.512***	0.583**	0.047
	(0.151)	(0.250)	(0.139)	(0.126)	(0.185)	(0.603)	(0.179)	(0.274)	(0.355)
DEUij	0.671***	0.684***	0.617***	0.219*	0.181	1.340*	− 0.746***	− 0.649***	− 0.807**
	(0.133)	(0.220)	(0.156)	(0.126)	(0.192)	(0.752)	(0.148)	(0.222)	(0.393)
Adjusted R^2	0.683	0.683		0.387	0.387		0.397	0.396	
Observations	15,552	15,552	15,552	15,552	15,552	15,552	15,552	15,552	15,552
Exporter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	Pooled OLS HS850300	RE model	*Xij*, PPML	Pooled OLS HS850490	RE model	*Xij*, PPML
	Parts of machines under heading 8502			Parts for transformers, converters and inductors		
Constant	33.141***	33.106***	19.713***	28.931***	28.813***	18.990***
	(0.718)	(1.216)	(0.547)	(0.686)	(1.197)	(0.540)

Table 2 (continued)

	Pooled OLS HS850300	RE model	*Xij*, PPML	Pooled OLS HS850490	RE model	*Xij*, PPML
	Parts of machines under heading 8502			Parts for transformers, converters and inductors		
ln(*Tariffij* + 1)	− 0.400***	− 0.308***	− 0.413***	− 0.308***	− 0.050	− 0.254***
	(0.068)	(0.102)	(0.053)	(0.080)	(0.111)	(0.069)
ln(*DISTij*)	− 2.380***	− 2.394***	− 0.793***	− 2.007***	− 2.030***	− 0.848***
	(0.059)	(0.101)	(0.040)	(0.056)	(0.100)	(0.038)
DCLij	1.102***	1.100***	0.392***	0.709***	0.723***	0.494***
	(0.137)	(0.228)	(0.086)	(0.128)	(0.218)	(0.107)
DAPECij	0.250	0.308	0.546***	1.261***	1.330***	0.967***
	(0.171)	(0.276)	(0.127)	(0.152)	(0.255)	(0.120)
DEUij	− 0.184	− 0.159	− 0.167	− 0.439***	− 0.375*	− 0.750***
	(0.147)	(0.242)	(0.133)	(0.136)	(0.225)	(0.117)
Adjusted R^2	0.665	0.665		0.681	0.681	
Observations	15,552	15,552	15,552	15,552	15,552	15,552
Exporter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

	Pooled OLS HS901380	RE model	*Xij*, PPML	Pooled OLS HS901390	RE model	*Xij*, PPML	Pooled OLS HS902610	RE model	*Xij*, PPML
	Heliostats orient mirrors in concentrated solar power			Parts of HS901380			Instruments for measuring or checking the flow, level, pressure or other variables of liquids or gases		
Constant	19.511***	19.564***	18.456***	17.977***	18.091***	15.439***	30.335***	30.306***	17.690***
	(0.695)	(1.168)	(1.037)	(0.670)	(1.109)	(1.280)	(0.662)	(1.122)	(0.644)

Table 2 (continued)

	Pooled OLS HS901380	RE model	*Xij*, PPML	Pooled OLS HS901390	RE model	*Xij*, PPML	Pooled OLS HS902610	RE model	*Xij*, PPML
	Heliostats orient mirrors in concentrated solar power			Parts of HS901380			Instruments for measuring or checking the flow, level, pressure or other variables of liquids or gases		
ln(*Tariffij* + 1)	− 0.011	0.025	0.261***	− 0.287***	− 0.196**	− 0.233	− 0.434***	− 0.312***	− 0.117*
	(0.073)	(0.102)	(0.090)	(0.079)	(0.083)	(0.160)	(0.090)	(0.120)	(0.066)
ln(*DISTij*)	− 1.467***	− 1.473***	− 0.967***	− 1.183***	− 1.196***	− 0.699***	− 1.923***	− 1.933***	− 0.554***
	(0.055)	(0.094)	(0.076)	(0.053)	(0.089)	(0.095)	(0.053)	(0.092)	(0.050)
DCLij	1.240***	1.240***	1.255***	1.031***	1.028***	1.274***	1.353***	1.353***	0.510***
	(0.124)	(0.203)	(0.170)	(0.121)	(0.202)	(0.246)	(0.125)	(0.210)	(0.067)
DAPECij	1.108***	1.115***	− 0.399	1.649***	1.663***	0.352	0.056	0.056	0.535***
	(0.159)	(0.255)	(0.275)	(0.159)	(0.266)	(0.305)	(0.146)	(0.235)	(0.128)
DEUij	0.390***	0.397*	− 0.417	− 0.387***	− 0.359*	− 0.832***	0.430***	0.416*	0.291**
	(0.136)	(0.220)	(0.274)	(0.132)	(0.214)	(0.282)	(0.131)	(0.212)	(0.113)
Adjusted R^2	0.657	0.657	0.965	0.629	0.629		0.679	0.679	
Observations	15,552	15,552	15,552	15,552	15,552	15,552	15,552	15,552	15,552
Exporter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 2 (continued)

	Pooled OLS HS902620	RE model	*Xij*, PPML	Pooled OLS HS902690	RE model	*Xij*, PPML
	Manometers for monitoring indoor air, etc. with many environmental applications			Parts for articles of subheading 9026		
Constant	26.153***	26.137***	15.171***	25.919***	25.937***	17.633***
	(0.612)	(1.025)	(0.450)	(0.631)	(1.036)	(0.397)
ln(*Tariffij* + 1)	− 0.242***	− 0.175**	− 0.193***	− 0.283***	− 0.259**	− 0.020
	(0.075)	(0.082)	(0.059)	(0.085)	(0.109)	(0.077)
ln(*DISTij*)	− 1.739***	− 1.744***	− 0.477***	− 1.719***	− 1.721***	− 0.664***
	(0.048)	(0.083)	(0.038)	(0.050)	(0.085)	(0.031)
DCLij	1.363***	1.364***	0.491***	1.209***	1.209***	0.192***
	(0.112)	(0.189)	(0.072)	(0.117)	(0.192)	(0.066)
DAPECij	0.452***	0.451**	0.607***	0.554***	0.553**	0.530***
	(0.138)	(0.225)	(0.099)	(0.142)	(0.225)	(0.097)
DEUij	0.708***	0.700***	0.390***	0.107	0.104	0.147
	(0.120)	(0.197)	(0.092)	(0.123)	(0.196)	(0.099)
Adjusted R^2	0.719	0.719	0.879	0.702	0.702	
Observations	15,552	15,552	15,552	15,552	15,552	15,552
Exporter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

X_{ij} is bilateral exports from country *i* to country *j* plus 1

Standard errors are shown in parentheses

***Shows significant at 1% level, ** at 5% level, and * at 10% level of ten. These goods are as follows: HS850300 (parts and components for electricity generation from renewable sources); HS850490 (parts for electrical transformers, static converters and inductors for renewable energy production); HS901380 (heliostats orient mirrors); HS901390 (parts and components of heliostats orient mirrors); HS902610 (instruments for monitoring environmental conditions); HS902620 (manometers for monitoring environmental conditions); and HS902690 (parts and components for monitoring environmental conditions).

The coefficients of DCL range between 0.709 for HS850490 and 1.363 for HS902620 in the pooled OLS; between 0.723 for HS850490 and 1.364 for HS902620 for random- effect model; and 0.192 for HS902690 and 0.494 for HS850490 in PPML. At the maximum, common official language makes countries' bilateral trade in HS902620 exp(1.364) − 1 = 291% larger in random-effect model, and at the minimum, common official language makes countries' bilateral trade 21% larger for HS902690 in PPML, everything else being equal.

To clarify the characteristics of the EGs for those effects, it is useful to compare the results here with those in Disdier et al. (2009) for cultural goods. If those effects in PPML for distance and common language for EGs are compared with those for cultural goods, the effects of distance between − 0.23 and − 1.04 for cultural goods are slightly smaller than in the case of EGs. On the other hand, the effects of common language (between 0.65 and 1.68) for cultural goods are much larger than the case of EGs, which are between 0.19 and 0.51. This shows that a common language has a larger impact on the trade in the cultural goods in which language is influential, while proximity has a larger impact on the trade in the EGs in which distance is influential with smaller transport cost.

4.3 Effects of regional integration

Trade integration established among the countries in each region may accelerate regional trade as a different effect from geographical proximity. Trade integration is established either by vertical integration, exchanging parts and components for a common final good based on international production fragmentation, or horizontal integration, exchanging final goods based on product differentiation. In fact, trade of parts and components for each final good has increased based on the production network through the supply chain, especially in East Asia.[8] In this paper, the effect of regional integration on the trade of each of the ten EGs is examined through the regional dummy variables for APEC, EU, and East and South-East Asia (ASEAN + 3, Hong Kong and Taiwan).

As for the EU dummy variable, the coefficients for only two goods, HS841290 (wind turbines and hubs) and HS902620 (manometer for monitoring the environmental conditions) are positive and significant at the 1% level in all the three estimation methods. In the case of HS841290, the coefficients are stable among the estimation methods, ranging between 0.617 and 0.684, which signifies that EU

[8] The pioneering empirical work for this topic is Ando and Kimura (2005). For the analysis of vertical intra-industry trade and fragmentation, see Türkcan and Ates (2011).

membership makes countries' bilateral trade 85.3% ~ 98.2% larger. For HS902620, the coefficients vary between 0.390 and 0.708, which signifies that EU membership makes countries' bilateral trade 47.7% ~ 103.0% larger.

On the other hand, the dummy variable for APEC is positive and significant (always significant at the 1% level, except for HS902690 in random-effect model which is significant at the 5% level) in all the three methods for four goods out of ten: these are HS841290 (wind turbines and hubs), HS850490 (parts for electrical transformers, static converters and inductors for renewable energy production), HS902620 (manometers for monitoring environmental conditions), and HS902690 (parts and components of instruments for monitoring environmental conditions). The coefficients vary between 0.490 for HS841290 in pooled OLS and 1.330 for HS850490 in random-effect model, which shows that APEC membership makes countries' bilateral trade 63.2% ~ 278.1% larger.

For HS850239 (electric generating sets and rotary converters for renewable energy production), HS901380 (heliostats orient mirrors), and HS901390 (parts and components for heliostats orient mirrors), the coefficients of the APEC dummy are positive and significant in the pooled OLS and random-effect model, but the effect is denied in PPML. However, for the case of HS850300 (parts for electricity generation from renewable resources), the APEC dummy is positive and significant only in PPML.

For the case of HS902620, the coefficients of both bilateral tariff rates and regional dummies of APEC and EU are significant with right sign at the 1% or 5% level, which makes clear that regional dummy variables are not a substitute for tariff rates. This suggests that membership in EU and APEC fosters trade flows not only through tariff reduction but also through regional elements.

To examine the effect of trade networks among the countries of ASEAN + 3 (including Hong Kong and Taiwan), Eq. (9) is estimated with the same methods as Eq. (8). The results are shown in Table 3. In all the regressions, the EU dummy variable, which is not significant, is omitted.

The estimated coefficients of the dummy variable of ASEAN + 3 are positive and significant at the 1% level in all the three estimation methods for three goods: these are HS850490 (parts for electrical transformers, static converters and inductors for renewable energy production); HS901380 (heliostats orient mirrors); and HS901390 (parts and components for heliostats orient mirrors). The exception is the coefficient in PPML of HS901390 which is significant at the 5% level. The magnitude of the coefficients in pooled OLS, random-effect model, and PPML are 2.158, 2.182, and 0.517, respectively, for HS850490; 1.822, 1.837, and 1.568, respectively, for HS901380; and 3.519, 3.531, and 1.066, respectively, for HS901390. Accordingly, considerably large effects are clarified for the trade network among East and South-East Asia in these goods. For example, this kind of trade network raises bilateral trade by a factor of $\exp(1.066) = 2.9$ to $\exp(3.531) = 34.2$ for HS901390; $\exp(1.568) = 4.8$ to $\exp(1.837) = 6.3$ for HS901380; and $\exp(0.517) = 1.7$ to $\exp(2.182) = 8.9$ for HS850490.

For the following goods, the coefficients of the dummy of ASEAN + 3 are positive and significant at the 1% level in both pooled OLS and random-effect model. These goods are HS841290 (wind turbines and hubs); HS850239 (electric generating sets and rotary convertors for renewable energy production); HS850300 (parts for electricity generation from renewable resources); HS902610 (instruments for

Table 3 Estimation results for gravity equation (9)

	Pooled OLS HS841290	RE model	*Xij*, PPML	Pooled OLS HS850231	RE model	*Xij*, PPML	Pooled OLS HS850239	RE model	*Xij*, PPML
	Integral components to wind turbines			Wind-powered electric generating sets			Electric generating sets, rotary convertors		
Constant	30.702***	30.728***	23.071***	9.121***	9.085***	24.186***	17.172***	17.268***	18.768***
	(0.595)	(1.021)	(0.501)	(0.617)	(0.940)	(1.677)	(0.729)	(1.133)	(1.124)
ln(Tariff + 1)	− 0.061	− 0.008	− 0.378***	− 0.084	− 0.114	− 0.063	− 0.303***	− 0.103	0.075
	(0.064)	(0.096)	(0.082)	(0.065)	(0.086)	(0.244)	(0.078)	(0.108)	(0.112)
ln(DIST)	− 2.006***	− 2.016***	− 0.851***	− 0.673***	− 0.666***	− 1.238***	− 1.190***	− 1.226***	− 0.844***
	(0.050)	(0.087)	(0.040)	(0.053)	(0.081)	(0.168)	(0.060)	(0.093)	(0.104)
DCL	1.013***	1.015***	0.061	0.491***	0.492***	0.291	0.960***	0.968***	-0.509**
	(0.121)	(0.206)	(0.092)	(0.122)	(0.184)	(0.324)	(0.155)	(0.241)	(0.231)
DAS3	1.344***	1.346***	-0.250	-0.046	-0.048	−1.706**	2.853***	2.885***	0.355
	(0.205)	(0.339)	(0.155)	(0.202)	(0.300)	(0.711)	(0.288)	(0.454)	(0.437)
Adjusted R^2	0.683	0.683	0.833	0.387	0.387	0.851	0.401	0.401	0.646
Observations	15,552	15,552	15,552	15,552	15,552	15,552	15,552	15,552	15,552
Exporter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	Pooled OLS HS850300	RE model	*Xij*, PPML	Pooled OLS HS850490	RE model	*Xij*, PPML
	Parts of machines under heading 8502			Parts for transformers, converters and inductors		
Constant	31.197***	31.277***	20.694***	28.328***	28.435***	19.615***
	(0.650)	(1.097)	(0.513)	(0.614)	(1.069)	(0.511)

Table 3 (continued)

	Pooled OLS	RE model	*Xij*, PPML	Pooled OLS	RE model	*Xij*, PPML
	HS850300			HS850490		
	Parts of machines under heading 8502			Parts for transformers, converters and inductors		
ln(Tariff + 1)	− 0.371***	− 0.292***	− 0.460***	− 0.351***	− 0.080	− 0.228***
	(0.065)	(0.097)	(0.047)	(0.078)	(0.109)	(0.067)
ln(DIST)	− 2.177***	− 2.198***	− 0.835***	− 1.867***	− 1.910***	− 0.800***
	(0.056)	(0.096)	(0.042)	(0.052)	(0.091)	(0.043)
DCL	1.129***	1.125***	0.393***	0.730***	0.741***	0.514***
	(0.137)	(0.228)	(0.082)	(0.127)	(0.217)	(0.103)
DAS3	1.977***	1.999***	0.011	2.158***	2.182***	0.517***
	(0.220)	(0.373)	(0.131)	(0.201)	(0.358)	(0.181)
Adjusted R^2	0.667	0.667	0.831	0.682	0.681	0.884
Observations	15,552	15,552	15,552	15,552	15,552	15,552
Exporter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

	Pooled OLS	RE model	*Xij*, PPML	Pooled OLS	RE model	*Xij*, PPML	Pooled OLS	RE model	*Xij*, PPML
	HS901380			HS901390			HS902610		
	Heliostats orient mirrors in concentrated solar power			Parts of HS901380			Instruments for measuring or checking the flow, level, pressure, or other variables of liquids or gases		
Constant	20.380***	20.434***	15.830***	17.028***	17.068***	13.657***	29.586***	29.526***	19.727***
	(0.645)	(1.089)	(0.891)	(0.616)	(1.019)	(0.997)	(0.580)	(0.971)	(0.384)
ln(Tariff + 1)	0.002	0.034	0.275***	− 0.156**	− 0.130	− 0.194	− 0.359***	− 0.267**	− 0.121*
	(0.074)	(0.104)	(0.082)	(0.077)	(0.082)	(0.153)	(0.090)	(0.118)	(0.064)

Table 3 (continued)

	Pooled OLS HS901380	RE model	*Xij*, PPML	Pooled OLS HS901390	RE model	*Xij*, PPML	Pooled OLS HS902610	RE model	*Xij*, PPML
	Heliostats orient mirrors in concentrated solar power			Parts of HS901380			Instruments for measuring or checking the flow, level, pressure, or other variables of liquids or gases		
ln(DIST)	− 1.496***	− 1.502***	− 0.685***	− 0.996***	− 1.001***	− 0.440***	− 1.860***	− 1.863***	− 0.708***
	(0.051)	(0.087)	(0.084)	(0.048)	(0.081)	(0.093)	(0.047)	(0.081)	(0.033)
DCL	1.228***	1.228***	1.182***	1.056***	1.055***	1.135***	1.353***	1.354***	0.481***
	(0.124)	(0.202)	(0.162)	(0.119)	(0.198)	(0.260)	(0.124)	(0.210)	(0.062)
DAS3	1.822***	1.837***	1.568***	3.519***	3.531***	1.066**	1.390***	1.409***	− 0.236*
	(0.241)	(0.396)	(0.337)	(0.248)	(0.431)	(0.427)	(0.203)	(0.339)	(0.133)
Adjusted R^2	0.657	0.657	0.965	0.633	0.633	0.906	0.679	0.679	0.849
Observations	15,552	15,552	15,552	15,552	15,552	15,552	15,552	15,552	15,552
Exporter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	Pooled OLS HS902620	RE model	*Xij*, PPML	Pooling OLS HS902690	RE model	*Xij*, PPML
	Manometers for monitoring indoor air, etc. with many environmental applications			Parts for articles of subheading 9026		
Constant	27.321***	27.297***	17.830***	25.935***	25.935***	19.577***
	(0.550)	(0.924)	(0.478)	(0.561)	(0.932)	(0.374)
ln(Tariff + 1)	− 0.177**	− 0.143*	− 0.166***	− 0.214**	− 0.215**	0.009
	(0.075)	(0.082)	(0.056)	(0.084)	(0.109)	(0.075)

Table 3 (continued)

	Pooled OLS	RE model	*Xij*, PPML	Pooling OLS	RE model	*Xij*, PPML
	HS902620			HS902690		
	Manometers for monitoring indoor air, etc. with many environmental applications			Parts for articles of subheading 9026		
ln(DIST)	− 1.844***	− 1.845***	− 0.685***	− 1.692***	− 1.692***	− 0.814***
	(0.044)	(0.076)	(0.045)	(0.045)	(0.077)	(0.033)
DCL	1.338***	1.339***	0.455***	1.210***	1.210***	0.198***
	(0.112)	(0.191)	(0.064)	(0.117)	(0.192)	(0.065)
DAS3	0.783***	0.790**	− 0.356**	1.179***	1.179***	− 0.326***
	(0.201)	(0.341)	(0.169)	(0.204)	(0.335)	(0.107)
Adjusted R^2	0.718	0.718	0.874	0.703	0.703	0.868
Observations	15,552	15,552	15,552	15,552	15,552	15,552
Exporter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

X_{ij} is log bilateral exports from country *i* to partner *j* plus 1

Standard errors are shown in parentheses

***Shows significant at 1% level, ** at 5% level, and * at 10% level monitoring air quality etc.); HS902620 (manometers for monitoring environmental conditions); and HS902690 (parts and components for monitoring environmental conditions). However, they are not positive and significant in PPML.

4.4 Regional integration and intra-industry trade

The effects of tariff rates and regional integration are summarized in Table 4 which shows the characteristics of trade for each EG. First, for HS850300 and HS902610, the effect of tariff rates is robustly significant, but this effect is not accompanied by the effect of any regional integration. Second, for HS902620, the robustly significant effect of tariff rates and regional integration of both EU and APEC are observed at the same time. Third, the regional integration of EU and APEC affects trade in each region for HS841290 which is an important item for wind-powered electric generation. Fourth, while the vertical trade of parts and components for HS850490 and HS901390 and the trade of the final good HS901380 are active in East and South-East Asia, the vertical trade of parts and components for HS841290, HS850490 and HS902690, and the trade of the final good of HS902620 are active in APEC (Table 4).

To examine the trade pattern of each country in each EG having robust effect of regional integration upon activation of regional trade shown in Table 4, the regional intra-industry trade (IIT) index is introduced. IIT is a country's two-way exchange of similar goods belonging to the same industrial classification.[9] IIT of final goods is based on product differentiation among goods of same category and IIT of the goods for parts and components is considered as two-way exchange of goods of different production stages of the same industry classification based on production fragmentation. The distinction of IIT between horizontal IIT and vertical IIT based on the quality differences is not included in this study.

The IIT index was developed by Grubel-Lloyd (1975). *GLi* is used to measure the share of IIT in a country's overall trade for good *i* as follows:

$$GL_i = 1 - \frac{\left|X_i - M_i\right|}{\left(X_i + M_i\right)}, \tag{10}$$

where X_i and M_i are the value of exports to the countries and imports from the countries in each region for the good *i*, respectively, in a particular country. The *GLi* index varies between 0 (complete inter-industry trade) and 1 (complete intra-industry trade) as a country's trade pattern.

Table 5 shows the IIT index for each country in the regional trade within APEC, EU, and ASEAN + 3 (including Hong Kong and Taiwan), respectively, for two selected years 2014 and 2017. The cases with IIT index over 0.40 are considered to be substantial with relatively high share of intra-industry trade in this study.

[9] See Krugman et al, (2017) and Türkcan et al. (2011).

Table 4 Significant Effects of Tariff Rates and Regional Integration

HS number	HS code description	Parts and components P&C) or final good (F)	Tariff rates	Region integration		
				EU	APEC	ASEAN + 3 (+ Hong Kong, Taiwan)
841290	Wind turbines and hubs	P & C		✓	✓	
850231	Wind-powered electric generating sets and equipment	F				
850239	Electric generating sets and rotary converters	F				
850300	Parts suitable for use with the machines of heading 8502	P & C	✓			
850490	Parts for electrical transformers, static converters and inductors	P & C			✓	✓
901380	Solar heliostats (optical devices, appliances and instruments)	F				✓
901390	Parts of solar heliostats (optical devices, appliances and so on)	P & C				✓
902610	Instruments for measuring or checking air quality	F	✓			
902620	Instruments for measuring or checking pressure	F	✓	✓	✓	
902690	Parts for articles of subheading 9026	P & C			✓	

Table 5 Intra-industry index for the region of APEC, EU, and ASEAN+3 (including Hong Kong and Taiwan)

APEC	HS841290 2014	HS841290 2017	HS850490 2014	HS850490 2017	HS902620 2014	HS902620 2017	HS902690 2014	HS902690 2017
Australia	**0.93**	0.28	0.33	**0.48**	0.13	0.18	0.33	**0.65**
Canada	**0.72**	**0.89**	**0.90**	**0.72**	**0.41**	**0.46**	**0.51**	**0.57**
Chile	0.27	0.22	0.05	0.04	0.34	0.05	0.01	0.02
China	**0.58**	**0.47**	**0.79**	**0.81**	**0.83**	**0.80**	**0.94**	**0.88**
HK	**0.62**	**0.90**	**0.58**	**0.48**	**0.84**	**0.79**	**0.98**	**0.82**
Indonesia	0.05	0.09	**0.65**	0.34	0.14	0.06	0.11	0.35
Japan	**0.95**	**0.93**	**0.93**	**0.92**	**0.96**	**0.98**	**0.41**	**0.40**
Korea	**0.93**	**0.81**	**0.66**	**0.67**	0.18	0.13	**0.51**	**0.97**
Malaysia	**0.42**	**0.53**	**0.62**	**0.42**	**0.49**	**0.78**	**0.76**	**0.93**
Mexico	0.19	0.20	**0.71**	**0.80**	**0.62**	**0.64**	**0.93**	**0.84**
New Zealand	**0.82**	**0.69**	**0.59**	**0.52**	0.28	0.22	0.33	0.11
Peru	0.06	0.04	0.03	0.02	0.04	0.03	0.02	0.09
Philippines	0.38	0.22	**0.58**	**0.47**	0.00	0.01	**0.64**	0.17
Russia	0.33	0.12	**0.52**	0.32	0.21	0.31	0.00	0.10
Singapore	0.37	**0.67**	**0.99**	**0.83**	**0.52**	**0.59**	**0.89**	**0.84**
Taiwan	**0.81**	**0.95**	**0.83**	**0.82**	**1.00**	**0.98**	**0.81**	**0.66**
Thailand	0.18	**0.66**	**0.65**	**0.65**	0.25	0.29	0.38	**0.65**
US	**0.97**	**0.77**	**0.64**	**0.60**	**0.99**	**0.98**	**0.94**	**0.95**
Vietnam	0.20	0.26	**0.65**	**0.85**	**0.84**	0.24	0.16	0.03

EU	HS841290 2014	HS841290 2017	HS902620 2014	HS902620 2017
Austria	0.05	0.09	0.04	0.04
Belgium	**0.97**	**0.76**	**0.74**	**0.62**
Bulgaria	**0.66**	0.35	**0.77**	0.29
Croatia	**0.66**	0.08	0.05	0.22
Cypress	0.00	0.12	0.00	0.06
Czech R	**0.45**	**0.67**	**0.69**	**0.78**
Denmark	0.19	0.14	**0.80**	**0.74**
Estonia	0.25	**0.60**	0.23	0.15
Finland	0.23	0.20	**0.40**	**0.66**
France	0.26	**0.71**	**0.82**	**0.79**
Germany	**0.97**	**0.96**	**0.56**	**0.54**
Greece	0.01	0.01	0.15	0.12
Hungary	**0.63**	**0.57**	0.10	0.06
Ireland	0.20	0.08	0.04	0.05
Italy	**0.81**	**0.75**	**0.45**	**0.44**
Latvia	**0.67**	**0.81**	**0.57**	0.23
Lithuania	0.37	**0.85**	0.35	0.23

Table 5 (continued)

EU	HS841290 2014	HS841290 2017	HS902620 2014	HS902620 2017
Luxembourg	**0.89**	**0.90**	**0.49**	0.38
Malta	0.00	0.00	0.00	0.00
Netherland	**0.56**	**0.51**	**0.47**	**0.69**
Poland	**0.44**	0.23	0.07	0.17
Portugal	**0.95**	**0.97**	**0.45**	**0.90**
Romania	**0.44**	0.23	0.07	0.17
Slovakia	0.27	**0.79**	0.29	0.21
Slovenia	0.31	**0.90**	**0.92**	**0.71**
Spain	0.16	0.31	**0.52**	0.38
Sweden	0.27	**0.70**	0.24	0.40
UK	0.17	0.08	**0.80**	**0.86**

ASEAN+3 (including HK and Taiwan)	HS850490 2014	HS850490 2017	HS901380 2014	HS901380 2017	HS901390 2014	HS901390 2017
China	**0.69**	**0.70**	**0.87**	**0.80**	0.37	**0.64**
HK	**0.60**	**0.48**	0.29	**0.42**	**0.53**	**0.48**
Indonesia	**0.53**	0.30	0.00	0.00	0.00	0.00
Japan	**0.78**	**0.97**	**0.44**	0.39	**0.91**	**0.49**
Korea	**0.63**	**0.66**	0.25	0.32	**0.79**	**0.48**
Malaysia	**0.54**	0.36	0.23	0.07	0.07	0.12
Philippines	**0.47**	0.25	0.01	0.06	0.00	0.00
Singapore	**0.96**	**0.86**	**0.62**	**0.70**	0.26	**0.46**
Taiwan	**0.71**	**0.72**	**0.44**	0.22	0.05	0.26
Thailand	**0.61**	**0.57**	0.01	0.01	0.32	0.16
Vietnam	**0.65**	**0.89**	0.00	0.14	0.01	0.04

Source: Author's calculation

For the APEC region, Canada, China, Hong Kong, Japan, Korea (except HS902620), Malaysia, Mexico (except HS841290), Singapore (except HS841290 in 2014), Taiwan, and the US have relatively high IIT index over 0.40. This shows that these countries actively exchange parts and components at different production stages based on production fragmentation for the items of parts and components, such as HS841290, HS850490, and HS902690. On the other hand, these countries exchange differentiated products of for the final good HS902620. The countries such as Chile, Indonesia, Peru, and Russia mainly depend on unilateral imports for these EGs. Australia, New Zealand, Philippines, Thailand, and Vietnam conduct intra-industry trade in some of the EGs included.

The EU, countries such as Belgium, Czech Republic, France (except HS841290 in 2014), Germany, Italy, Luxembourg (except HS902620 in 2017), the Netherlands, Portugal, and Slovenia (except HS841290 in 2014) have a high

IIT index over 0.40 for both EGs. For Sweden, the index for both HS841290 and HS902620 increased to over 40 in 2017. The United Kingdom has a high index only for HS902620 with exchange of the differentiated final good, and Hungary does only for HS841290 with the exchange of parts and components, for both years.

For the region of East and South-East Asia, HS850490 is the EG with a high IIT index over 0.40 for all the countries for both years (except Indonesia, Malaysia and Philippines for only 2014). For the other two EGs, although trade among the countries is active due to regional integration, the IIT is confirmed only for China, Hong Kong, Japan, Korea, Singapore and Taiwan for some years.

Accordingly, the trade pattern of each country in regional trade networks for each EG is clearly identified by examining IIT index for each country within each region. For most cases in developed countries and some emerging countries, a high IIT index is shown based on both product differentiation for EGs of final good and vertical differentiation with production fragmentation for EGs of parts and components, in the presence of regional integration. The regional trade networks for specific EGs are shown to be based on the exchange of the same kind of EGs to consolidate the environmental protection system.

5 Conclusions

This paper investigates the major determinants of trade of ten disaggregated EGs selected from the APEC list which aims at environmental protection focusing on renewable energy production and monitoring environmental conditions. The analysis is based on the fixed effect approach of the gravity model, and the estimations are conducted with three methods: pooled OLS, random-effect model and PPML for 4 years between 2013 and 2016 including 73 countries.

First, through examination of the estimation results for the effects of bilateral tariff rates, the good-specific characteristics are clarified. For three out of the ten EGs, the coefficients of the bilateral tariff rates are negative and significant in all three methods, showing the relatively modest elasticities ranging between 0.117 and 0.434. Second, while all of the ten EGs examined in this study are impacted by distance with relatively large effect, seven goods are impacted by common language with smaller coefficients. Despite the coefficients varying among the goods and estimation methods, these results clearly show the impact of distance between two countries. This signifies that trade of all the EGs examined in this paper is quite active among the countries closer to each other due to cheaper transport costs.

Third, although the effect of joining in the trade networks of ASEAN + 3 (including Hong Kong and Taiwan) is clarified only for three goods, the coefficients of these three EGs are much larger than the cases of EU and APEC. Accordingly, quite tight trade networks could possibly be constructed in those EGs examined in this paper, among the East and South-East Asian countries. Fourth, as for the EU dummy variable, the coefficients for only two goods, HS841290 and HS902620, are positive and significant at the 1% level in all the three estimation methods. For the APEC dummy variable, the coefficients of four EGs, HS841290, HS850490, HS902620, and HS902690, are positive and significant in all the three methods.

The empirical substitutability between the effects of tariff rates and those of regional integration are clarified by examining the effects of tariff rates and regional integration together. For the case of HS902620, as the coefficients of both bilateral tariff rates and regional dummies of APEC and EU are significant with right sign at the 1% or 5% level, it is clarified that regional dummy variables are not substitutes for tariff rates. For HS850300, while the coefficients of tariff rates are significant at the 1% level and stable among the three estimation methods, the effects of regional integration are not accompanied. Also for HS850490, while the effect of APEC membership is very large and stable among the three estimation methods, the effect of tariff rates is not clarified in random-effect model. Accordingly, for the latter two EGs, either effect can empirically be a substitute for the other.

In the presence of regional integration, by examining the IIT index in each country within each region, it can be seen that the developed countries and some emerging countries tend to have high IIT indices based on either product differentiation for EGs of final goods or vertical differentiation with production fragmentation for EGs of parts and components.

From this detailed investigation for the effects on the trade of each EG, trade expansion through tariff reduction and regional integration is made clear for specific EGs examined in this study. Therefore, it is worth the effort to continue reducing tariff rates on more EGs and to strengthen regional trade networks among APEC and WTO members engaged in plurilateral trade negotiations to expand trade in EGs intended for environmental protection.

Appendix 1

Table 6 shows countries included in this study.

Table 6 Countries included in this study

Exporting and importing countries			Importing countries
APEC	EU	Others	
Australia	Austria	Brazil	Algeria
Canada	Belgium	India	Argentina
Chile	Bulgaria	Israel	Bangladesh
China	Croatia	Norway	Belarus
Hong Kong	Cypress	South Africa	Cambodia
Indonesia	Czech Republic	Switzerland	Colombia
Japan	Denmark	Turkey	Costa Rica
Korea	Estonia		Egypt
Malaysia	Finland		Ghana
Mexico	France		Kazakhstan
New Zealand	Germany		Kenia
Papua New Guinea *	Greece		Myanmar
Peru	Hungary		Nigeria
Philippines	Ireland		Paraguay
Russia	Italy		Saudi Arabia
Singapore	Latvia		Ukraine
Taiwan	Lithuania		United Arab Emirates
Thailand	Luxembourg		Uruguay
United States	Malta		
Vietnam	Netherland		
	Poland		
	Portugal		
	Romania		
	Slovakia		
	Slovenia		
	Spain		
	Sweden		
	United Kingdom		

*Papua New Guinea is included in the study only as importing country, though it is listed in the group of APEC not in the group of importing countries

Appendix 2

Table 7 shows descriptive statistics for ten EGs included in the study.

Table 7 Descriptive statistics

HS841290 variable	ln(export)	ln(tariff)	ln(distance)	Common language dummy	APEC dummy	EU dummy	ASEAN + 3 dummy
Observations	15,552	15,552	15,552	15,552	15,552	15,552	15,552
Mean	6.69	0.68	8.47	0.08	0.09	0.19	0.03
Standard deviation	5.98	0.85	1.01	0.27	0.29	0.40	0.18
Minimum	0.00	0.00	4.09	0	0	0	0
Maximum	20.47	2.77	11.70	1	1	1	1

HS850231			HS850239			HS850300		
Variable	ln(export)	ln(tariff)	Variable	ln(export)	ln(tariff)	Variable	ln(export)	ln(tariff)
Observations	15,552	15,552	Observations	15,552	15,552	Observations	15,552	15,552
Mean	1.39	0.58	Mean	2.66	0.47	Mean	7.67	0.69
Standard deviation	3.98	0.81	Standard deviation	4.97	0.75	Standard deviation	6.41	0.90
Minimum	0.00	0.00	Minimum	0	0	Minimum	0.00	0.00
Maximum	21.52	2.71	Maximum	19.88	2.71	Maximum	20.54	2.77

HS850490			HS901380			HS901390		
Variable	ln(export)	ln(tariff)	Variable	ln(export)	ln(tariff)	Variable	ln(export)	ln(tariff)
Observations	15,552	15,552	Observations	15,552	15,552	Observations	15,552	15,552
Mean	7.90	0.59	Mean	5.33	0.60	Mean	4.23	0.53
Standard deviation	6.04	0.89	Standard deviation	5.97	0.87	Standard deviation	5.59	0.84
Minimum	0.00	0.00	Minimum	0	0	Minimum	0	0
Maximum	21.346	3.078	Maximum	23.49	3.58	Maximum	22.46	3.58

Table 7 (continued)

HS902610			HS902620			HS902690		
Variable	ln(export)	ln(tariff)	Variable	ln(export)	ln(tariff)	Variable	ln(export)	ln(tariff)
Observations	15,552	15,552	Observations	15,552	15,552	Observations	15,552	15,552
Mean	7.54	0.34	Mean	7.66	0.37	Mean	6.90	0.32
Standard deviation	5.86	0.77	Standard deviation	5.79	0.81	Standard deviation	5.78	0.80
Minimum	0.00	0.00	Minimum	0	0	Minimum	0.00	0.00
Maximum	19.19	2.77	Maximum	20.01	2.94	Maximum	19.08	2.83

As the descriptive statistics for ln (distance), Common language dummy, APEC dummy, EU dummy, and ASEAN + 3 dummy are common for all the goods, those are given for the first good

Acknowledgements The author would like to acknowledge participants of 78th Annual Meeting of the Japan Society of International Economics on September 29, 2019 for their insightful comments and suggestions.

Funding This research is funded by Grants-in Aid Scientific Research (C), Japan Society for the Promotion of Science, no.17K03703.

References

Anderson JE (2010) The gravity model. (NBER working paper 16576). National Bureau of Economic Research, Cambridge, MA.

Anderson JE, van Wincoop E (2003) Gravity with gravitas: a solution to the border puzzle. Am Econ Rev 93(1):170–192

Ando M, Kimura F (2005) The formation of international production and distribution networks in East Asia. In: Ito T, Rose AK (eds) International Trade in East Asia, NBER-East Asia Seminar, Volume, 14. The University of Chicago Press, Chicago, pp 177–213

APEC (Asia-Pacific Economic Cooperation) (2012) Vladivostok Declaration-Integrate to Grow, Innovate to Prosper. http://www.apec.prg.

Cantore N, Fang C, Cheng C (2018) International trade of environmental goods in gravity model. J Environ Manag 223:1047–1060

De Benedictis L, Taglioni D (2011) The gravity model in international trade. In De Benedictis, L and Salvatici, L. (Eds.) The trade Impact of European Union Preferential Policies. Springer, New York

Disdier AC, Silvio HTT, Fontagné L, Mayer T (2009) Bilateral trade of cultural goods. Rev World Econ 145(1):575–595

Disdier AC, Fontagné L, Mimouni M (2015) Tariff liberalization and trade integration of emerging countries. Rev Int Econ 23(5):946–971

Fally T (2015) Structural gravity and fixed effects. J Int Econ 97:76–85

Feenstra RC (2016) Advanced international trade, theory and evidence, 2nd edn. Princeton University Press, Princeton and Oxford

Grubel HG, Lloyd PJ (1975) Intra-industry trade: the theory and measurement of international trade in differentiated products. Wiley, New York

Hayakawa K (2013) How serious is the omission of bilateral tariff rates in gravity? J JpnInt Econ 27:81–94

Head K, Mayer T (2014) Gravity equations: workhorse, toolkit, and cookbook. In Gopinath, Helpman, E. and Rogoff, K. (eds.) Handbook of International Economics, vol. 4, Elsevier B.V., Amsterdam

International Institute for Sustainable Development (IISD) and United Nations Environmental Programme (UNEP) (2014) Trade and green economy: a handbook, 3rd edn. IISD, Geneva

Jomit CP (2014) Export potential of environmental goods in india: a gravity model analysis. Transnatl Corp Rev 6(2):115–131

Krugman PR, Obstfeld M, Melitz MJ (2017) International economics: theory and policy, 11th Edition.

Kuik OJ, Branger F, Quiron P (2018) Competitive advantage in the renewable energy industry: evidence from a gravity model. Renew Energy 131:472–481

Matsumura A (2016a) Regional trade integration by environmental goods. J Econ Integr 31(1):1–40

Matsumura A (2016b) World trade flows in photovoltaic cells. J Tokyo IntUniv Econ Res 1:19–33

Matsumura A (2019) The effects of tariffs and regions on bilateral trade for environmental goods: cases for some renewable energy goods. J JpnAcadInt Trade Bus 56:3–21

Nunez-Rocha T, Martinez-Zarzoso I (2018) Are international environmental policies effective? The case of the Rotterdam and the Stockholm conventions. Discussion papers 333, Center for European Governance and Economic Development Research, Gottingen

Redding SJ, Venables AJ (2004) Economic geography and international inequality. J Int Econ 62(1):53–62

Silva JMCS, Tenreyro S (2006) The log of gravity. Rev Econ Stat 88(4):641–658

Tanaka A (2015) New new trade theory (written in Japanese). Minerva Publisher, Tokyo

Türkcan K, Ates A (2011) Vertical intra-industry trade and fragmentation: an empirical examination of the US auto-parts industry. World Econ 34(12):154–172

United Nations Environment Programme (UNEP) (2012) Trade and environment briefings: trade in environmental goods, Policy Brief 6. New York, United Nations.
United Nations Environmental Programme (UNEP) (2014) Green economy, South–South trade in renewable energy. New York, United Nations.
World Trade Organization (2009) Trade and climate change, world trade organization-United Nations Environmental Programme Report, Geneva: WTO and UNEP (United Nations Environment Programme).
World Trade Organization (2011) Universe of environmental goods: official HS descriptions: committee on trade and environment special session TN/TE/20. WTO, Geneva

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.