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Effect of environmental regulations on China's graphite export

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A B S T R A C T

The disparity between import and export prices of China's graphite products indicates that China suffers a heavy loss of graphite resources. China's graphite resource abundance doesn't transform into an economic advantage. This paper tries to promote sustainable use of China's graphite resources by investigating the effect of environmental regulations on China's graphite resource export. Based on the gravity model and the panel data of the top 30 countries that imported graphite resources from China during 2005–2014, economical mass, population, graphite export price, export duty refund (EDR), language, recession and political conflicts are selected as measurable indicators of environmental regulations to study how the corresponding changes affect graphite export values. The results demonstrate that the determinants of China's graphite export values include economical mass, export price, export duty refund, and language. Policy recommendations are then raised in order to improve sustainable development of China's graphite industry.

1. Introduction

Graphite is a polymorph mineral and a stable form of carbon (Vovchenko et al., 2007). Due to its unique physical and chemical properties, it has been widely used in both traditional and modern industries. It is estimated that China's graphite demand will reach 100 million tons in 2020, increased by 42.5% relative to the 2010 level (Gao et al., 2015). According to the United States Geological Survey (USGS), China's graphite reserve is the largest in the world. Meanwhile, China is the largest graphite producer and exporter in the world (Bai et al., 2015). However, China's graphite industry is facing many challenges, among which the most serious one is its lower export prices due to irrational competition among different Chinese exporters (Wang and Zhu, 2014). Such a reality induces other countries to import a large amount of raw graphite resources from China, instead of mining their own graphite resources (Cui et al., 2012; Yu, 2014). For example, the US also has large graphite reserves. However, they restrict graphite mining and import from China. Without any new policy interventions, China's graphite resources will be depleted within 20 years (Wang and Zhu, 2014). Ironically, due to a lack of advanced technologies, China has to import graphite-based value-added products at much higher prices. In addition, graphite mining activities led to many environmental problems, such as groundwater and soil contaminations, air pollution, and mining solid wastes. However, these environmental externalities have not been internalized into their market prices

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(Chen, 2014). Under such a circumstance, it is critical to evaluate how innovative environmental regulations may help China's graphite industry move toward sustainable development.

Academically, most relevant studies focus on how one specific environmental policy may have impacts on different goods, such as clothes and food (Otsuki et al., 2001; Li and Jiang, 2009), but few studies focus on the strategic minerals. With regard to graphite, several studies have been conducted, such as statistical analysis on China's and world's graphite production, consumption and international trade, and qualitative analysis of existing problems on graphite mining (Wang, 2006; Li et al., 2008; Yan, 2014; Cui et al., 2012). Also, quantitative analysis on graphite import and export volumes and prices has been conducted (Bai et al., 2015). However, none of them quantitatively evaluated the impact of environmental regulations on graphite export, a useful measure on protecting the loss of graphite resource.

The methods for studying environmental policies and international trade can be categorized into three types, namely, the exploratory approach, the input-output analysis approach, and the econometric approach (Mulatu et al., 2001). The exploratory approach is suitable to study whether a shift of pollution-intensive industries from developed countries to developing countries has occurred. The underlying assumption is that such a shift is due to less strict environmental standards in developing countries (Mulatu et al., 2001; Jankowski et al., 2014). The input-output analysis approach was proposed by Leontief (1970) and can be used to calculate the overall abatement costs of imports and exports (Miller and Blair, 2009). The econometric approach is based on either the Heckscher–Ohlin (H–O) model or on the gravity model. The H–O model relies on the following assumptions: factor immobility between countries, perfect factor mobility among industries, identical technologies in all countries, and different endowments of productive factors (Bekkers and Stehrer, 2015; Sen, 2015), while the gravity model is frequently used to model bilateral trade (Helpman and Krugman, 1985; Mulatu et al., 2001; Didia et al., 2015; Liu et al., 2016). The main disadvantage of the H–O model is that it is based on multilateral trade flows, implying that different effects of environmental policies on various trade flows may be neutralized due to an aggregation of bilateral trade flows to a multilateral trade flow. In order to avoid this problem, van Beers and van den Bergh (1997) undertook a more disaggregate analysis, based on a bilateral trade flow equation. Further, they proposed a gravity model to avoid the problems that the H–O model brought (van Beers and van den Bergh, 2000). Therefore, the gravity model is selected in this study to investigate the effect of environmental regulations on China's graphite export.

In view of these research progresses, this paper aims to uncover the quantitative relationship between environmental regulations and the graphite export values based on the export values during 2005–2014 so that the current graphite export market can be better managed and sustainable use of graphite resource can be achieved. Particularly, we regard the export price as a variable of environmental regulations to uncover its influence on graphite export because the natural graphite price has been decreased (Liu, 2016), especially during the past few years. The current price is about 60% lower than the price prior to 1990s. As a result, the production of graphite is out of order, and the overall benefits significantly decline. Under such a circumstance, price is introduced in the proposed gravity model as one variable to investigate its effect on China's graphite export. Such an effort can help provide valuable policy insights to better manage the depleting graphite resources and avoid irrational export of such natural resources. In order to achieve such a target, the whole paper is organized as below. After this introduction section, Section 2 depicts the methods for this study, including data collection and treatment. Section 3 presents the research results. Section 4 discusses policy implications and Section 5 draws research conclusions.

2. Methods and data

2.1. Gravity model

Panel data are known as longitudinal or cross-sectional time-series data and can be used to observe the behaviors of entities (such as states, companies, individuals, countries, etc) across time (Torres-Reyna, 2007). To avoid spurious regression and make sure that the estimations are unbiased, a unit root test should be performed for stationarity of time series data (Zhang, 2016). After the panel data pass the stationarity test, the subtype model and the statistics of the gravity model can be respectively selected and explained. Details are described as follows.

2.1.1. LLC (Levin-Lin-Chu) test

Generally, the LLC test is used to test the stationarity of the panel data (Chen, 2014). If $P > 0.05$, null hypothesis is accepted and the data are unstable, otherwise they are stable. The value of P is calculated by the software of Eviews6.0.

2.1.2. Model selection and statistics explanation

Panel data models can be divided into two groups: fixed effect model and random effect model. If it's non-panel data, multiple regression model with pooled samples OLS (Ordinary Least Square) is generally used (Li and Jiang, 2009). First, it needs to test the significance of a panel data model. For this purpose, panel data are estimated by using fixed effect regression. Then, a Redundant Fixed Effects-likelihood Ratio Test is applied to determine whether regression with pooled samples OLS or panel data regression will be used. In the next step, panel data are calculated by using random effect regression, after which a Correlated Random Effect-Hausman Test is applied to determine whether fixed effect or random effect model will be used.

These models involve statistical analysis: R-squared, Adjusted R-squared, F-statistic and Probability (F-statistic). R-squared, ranging from 0 to 1, is defined as the overall fit of the model in terms of the correlation between the fitted and observed values of the dependent variable. The value close to 1 indicates a better fit. F-statistic tests the significance level of linear relationship, where the larger the value, the better. Probability (F-statistic, with a value less than 0.05) represents significant regression.

2.1.3. The traditional gravity equation

Tinbergen initiated the “gravity model” (Didia et al., 2015). Such a model is very effective and reliable in predicting the flows of bilateral trade between two countries or trading entities (Anderson, 1979; Bergstrand, 1989; Deardorff, 1998; Feenstra et al., 2001; Haveman and Hummels, 2004). The traditional gravity equation is shown below (Krisztin and Fischer, 2015):

$$Y_{ij} = \beta_0 X_i^{\beta_1} X_j^{\beta_2} D_{ij}^{\beta_3} \quad (1)$$

Typically, the stochastic version of the gravity equation has the following form:

$$Y_{ij} = \beta_0 X_i^{\beta_1} X_j^{\beta_2} D_{ij}^{\beta_3} \mu_{ij} \quad (2)$$

The basic gravity model specified by Anderson (1979) and Bergstrand (1989) can be expressed as below (Didia et al., 2015):

Table 1
Description and the coefficient sign prediction of the variables in Equation (5).

Variables	The description of variables	Coefficient sign prediction	Reasons
β_0	Constant		
EXP_{ijt}	Graphite export flow from country i to country j in year t (US $).		
$GDP_{it}*GDP_{jt}$	Gross Domestic Product of country i times that of country j in year t.	+	The variable represents economical mass. The larger of it, the larger of bilateral trade flow (Chen, 2014).
$POP_{it}*POP_{jt}$	Population of country i times that of country j in year t.	−	The effect of domestic deepening division is greater than demand that are both generated by the increasing population due to the particularity of graphite.
PR_{ijt}	Graphite export price of country i to country j in year t (unit: $/kg).	+	The higher the graphite' export price, the more incentive for enterprise.
EDR_{ijt}	Chinese Export Duty Refund of graphite in year t.	+	The higher the graphite EDR, the more incentive for enterprise (Li and Jiang, 2009).
LAN_t	Language, a dummy with value 1 if both country i and country j use the same language and zero otherwise.	+	If both country i and country j use the same language, it will save time and cost for translation, thus the total trade costs decrease greatly (Chen, 2014).
REC_t	Recession, a dummy with value 1 if both country i and country j are in recession years and zero otherwise.	−	China's graphite export value decreased due to the recession (Yin, 2011).
POL_t	Politics, a dummy with value 1 if country i and country j are in political conflict and zero otherwise.	−	China's graphite export value decreased due to the Diaoyu Island Incident in 2012 (Yan, 2014).
μ_i	Log-normally disturbance term		

$$Y_{ij} = \beta_0 X_i^{\beta_1} X_j^{\beta_2} D_{ij}^{\beta_3} A_{ij}^{\beta_4} \mu_{ij} \quad (3)$$

where Y_{ij} is the dollar value of the trade flow from country i to country j; $X_i(X_j)$ is the US dollar value of nominal GDP in i (j); D_{ij} is the distance from the economic center of i to that of j; A_{ij} is any other factor(s) either aiding or inhibiting trade between i and j; μ_{ij} is a log-normally distributed error term with $E(\mathrm{Ln}\mu_{ij}) = 0$. Theoretically, for variables X_i, X_j, D_{ij} in the traditional gravity model there is a positive relationship between X_i, X_j and Y_{ij}. For D_{ij}, which represents proxy's transportation costs, a negative relationship is expected. Hence, $\beta_1 > 0, \beta_2 > 0, \beta_3 < 0$. For A_{ij}, which captures a wide array of factors such as infrastructure variables, economic policy variables, and internal political climate variables, one can expect positive or negative relationships ($\beta_4 >$ or < 0), depending on how the variables are introduced into the regression model (Didia et al., 2015).

The most prevalent approach to estimate the multiplicative gravity model for the trade given by Equation (2) is to use a log-log transformation yielding:

$$\ln Y_{ij} = \ln\beta_0 + \beta_1 lnX_i + \beta_2 lnX_j + \beta_3 lnD_{ij} + \beta_4 lnA_{ij} + \ln\mu_{ij} \quad (4)$$

After that it would be to estimate the parameters of interest by ordinary least squares (OLS) (Krisztin and Fischer, 2015).

2.1.4. Improved gravity model

In this paper, the panel data of the top 30 countries that imported graphite resources from China during 2005–2014 are analyzed by adopting the gravity model. The specific variables of environmental regulations and the selection reasons are shown in Table 1. Based on these, the improved gravity model is illustrated in Equation (5).

$$\begin{aligned} \mathrm{LnEXP}_{ijt} = {} & \beta_0 + \beta_1 \ln(\mathrm{GDP}_{it}*\mathrm{GDP}_{jt}) + \beta_2 \ln(\mathrm{POP}_{it}*\mathrm{POP}_{jt}) \\ & + \beta_3 \ln\mathrm{PR}_{jt} + \beta_4 \ln\mathrm{EDR}_{ijt} + \beta_5 \mathrm{LAN}_t + \beta_6 \mathrm{REC}_t \\ & + \beta_7 \mathrm{POL}_t + \mu_i \end{aligned} \quad (5)$$

The export price equals to the total export value divided by the total weight. The EDR of every subgroup of graphite varies, thus average EDR value is used in this study. The EDR of China's graphite export to sample countries can be calculated by multiplying the EDR of every subcategory of graphite with the ratio of its export value proportion in the total graphite export value.

2.2. Data sources

The sources of the raw data come from different sources and are shown in Table 2.

The sample countries are the top 30 countries that imported graphite resources from China for the period of 2005–2014. Fig. 1 shows the graphite flows between China and its top 30 importers.

3. Results

3.1. The results of LLC test

The test results are shown in Table 3. All the P value of LnEXP_{ijt}, $\mathrm{Ln}(\mathrm{GDP}_{it}*\mathrm{GDP}_{jt})$, $\mathrm{Ln}(\mathrm{POP}_{it}*\mathrm{POP}_{jt})$, $\mathrm{Ln}(\mathrm{PR}_{ijt})$, $\mathrm{Ln}(\mathrm{EDR}_{ijt})$, REC_t and POL_t are less than 0.05. Therefore, the panel data are stable and significantly consistent, indicating that empirical regression analysis is feasible in this study.

3.2. Estimations

Eviews6.0 software is the main calculation software in this study. Table 4 shows the results of Redundant Fixed Effects-likelihood Ratio Test. Panel data are used for estimation since the

Table 2
The sources of the raw data.

Terms	Source
EXP, Price	The United Nations Comtrade database: http://comtrade.in.org/db/
GDP, POP	World Bank database: http://data.worldbank.org/indicator
EDR	Chinese Export Rebate Consult database: http://www.taxrefund.com.cn/cess/
LAN	Baidu Baike: http://baike.baidu.com

Notes: ①The distance between country i to country j is constant in the study period based on panel data. Therefore, the distance variables are not taken into consideration and introducing the price, EDR, recession and political incident variables due to the particularity of graphite.
②Due to numerous types of graphite and their corresponding data to count, only the main categories of graphite are analyzed.

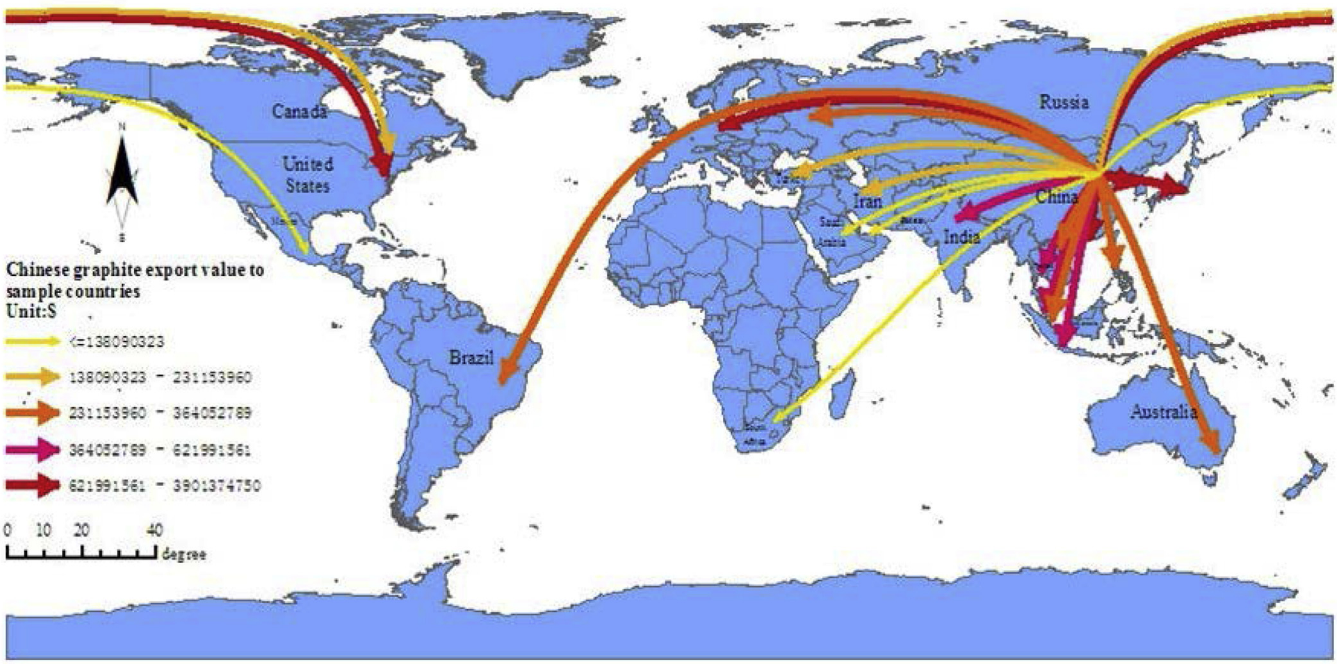

Fig. 1. The top 30 countries that imported graphite from China during 2005–2014.

P-value approaches to zero and the effect is significant. Based on $P < 0.05$ in Table 5, a random effect model is adopted. Because the number of cross-section data samples is more than that of the period data samples, a cross-section random effect model is selected.

3.3. The empirical analysis results

Table 6 shows the empirical analysis results of China's graphite export flows to sample countries. In the random effect model, statistically significant regressions can be observed (as revealed by the high F-statistic value) (Didia et al., 2015).

As shown in Table 6, the determinants of China's graphite export value to sample countries include the economical mass (GDP_{it}*GDP_{jt}), export price (PR_{ijt}), EDR and language (LAN), all of which reached a significant level. The multi-collinearity may exist between the dummy variables of REC and POL, thus the signs of the two aren't consistent with the predicted ones, leading these two variables to be rejected. Further analysis is as follows:

3.3.1. GDP

The regression coefficient of the economical mass (GDP_{it}*GDP_{jt}) is considerably positive. It implies that there is a positive correlation between China's graphite export values to importers and bilaterally economic mass, which is consistent with the prediction. The coefficient reaches up to 0.91, which indicates that the economic mass is the significant factor to China's graphite export value. It's consistent with the previous research outcomes that with the development of economy, the graphite trade values increase. In the traditional gravity model, the GDP is also one of the most important factors (Zhao and Lin, 2008).

In the reality, the top 30 countries that imported graphite resources from China are also the top GDP countries in the world, such as the US, Japan (China's largest graphite importer), and the UK. In order to meet the increasing demand of fast economic development, these countries import a large amount of natural resources, including graphite resources. Meanwhile, most graphite resources are reserved in few developing countries, among which China has more than 70% graphite reserves according to the USGS. In addition, China's graphite export prices are much lower than import prices, leading to those developed countries to import graphite resources from China.

Table 3
The results of LLC test.

Variables	Statistical method	Statistic	P-value	Results
$LnEXP_{ijt}$	I&T	−9.01834	0.0000	stable
Ln(GDP_{it}*GDP_{jt})	I&T	−13.4065	0.0000	stable
Ln(POP_{it}*POP_{jt})	I&T	−26.2254	0.0000	stable
Ln(PR_{ijt})	I&T	−11.7372	0.0000	stable
Ln(EDR_{ijt})	I&T	−8.61917	0.0000	stable
REC_t	I&T	−12.5201	0.0000	stable
POL_t	I&T	−1.91805	0.0276	stable

Notes: ①I&T means including intercept and trend items (Chen, 2014).

Table 4
The results of Redundant Fixed Effects-likelihood Ratio Test.

Effects Test	Statistic	d.f.	Prob.
Cross-section F	82.552681	(27,238)	0.0000
Cross-section Chi-square	654.767674	27	0.0000
Period F	4.103680	(9238)	0.0001
Period Chi-square	40.392016	9	0.0000
Cross-section/Period F	66.361714	(36,238)	0.0000
Cross-section/Period Chi-square	672.373906	36	0.0000

Table 5
The results of Correlated Random Effect-Hausman Test.

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	34.875160	6	0.0000

Table 6
The empirical analysis results of China's graphite export flow to sample countries.

Variables	Pooled model	Fixed effect model	Random effect model
Constant	−8.613786*** (−3.219400)	−55.46818** (−9.923870)	−34.07656*** (−7.763294)
$Ln(GDP_{it}*GDP_{jt})$	0.422619*** (9.616753)	1.316651*** (12.84883)	0.913439*** (11.49586)
$Ln(POP_{it}*POP_{jt})$	0.033023 (0.930529)	−0.028737 (−1.013126)	−0.006871 (−0.245494)
$Ln(PR_{ijt})$	−0.027830 (−0.281257)	0.236882*** (4.005285)	0.293687*** (5.139237)
$Ln(EDR_{ijt})$	−0.193671*** (−6.360643)	4.005285 (−0.804472)	−0.071663*** (−4.145532)
LAN_t	1.620762*** (6.934061)	–	1.877510*** (3.102014)
REC_t	0.176645 (1.284425)	0.004316 (0.078757)	0.055899 (1.042685)
POL_t	1.541990* (1.755583)	0.011335 (0.033969)	−0.051313 (−0.150713)
Total pool (balanced) observations	300	290	300
R-squared	0.422996	0.931352	0.713480
Adjusted R-squared	0.409164	0.922199	0.706611
F-statistic	30.58033	101.7531	103.8752
P (F-statistic)	0.000000	0.000000	0.000000
Hausman Test	–	–	1.0000 (0.000000)

Notes: *** = significant at 1%; ** = significant at 5%; * = significant at 10%. The numbers before brackets are regression coefficients. T-values in parentheses. "+" and "−" respectively indicates the positive and negative relationship. In the fixed effect model, variable LAN can't be estimated due to the existence of singular matrix. Therefore, this column is blank.

3.3.2. Population

The population variable hinders the bilateral trade, which is consistent with the prediction. Different researchers drew different conclusions on whether the population has a positive or negative effect on trade from different empirical analysis results. Some results show that there is a significantly negative correlation between the population and the trade flow based on General Equilibrium Theory (Zhao and Lin, 2008), while Brada and Méndez (1985) found a positive correlation between the population size and the trade flow. It indicates that the population variable has a dual effect on trade. On one hand, large countries have more diversified production and thus satisfy a greater proportion of domestic demand while small countries tend to be more specialized and thus more dependent on trade, suggesting that the coefficient of population should be negative for export countries. On another hand, the population of the import countries should have a positive effect on the volume of trade since a large population permits a greater labor division and production diversity, enabling imported products to compete with domestic products. Moreover, a large market better compensates exporters for the cost of acquiring information, establishing its sales and distributions network. Based on these two reasons, the coefficient should be positive (Brada and Méndez, 1985). In addition, with the more diversified labor distribution and increasing demand, the results show that the population size has a negative effect on graphite export, leading to that the empirical results are not significant. It indicates that the impact of diversified labor distribution is higher than the increasing demand since the significant difference between the population size of China and the sample countries reduced the population effect.

3.3.3. Export price

There is a positive correlation between the export values and prices, which is the focal point of this study. Graphite products import prices from Japan to China are selected to compare with the export prices because Japan is the largest graphite products exporter to China, with over 90% of China's total graphite import volume (Yan, 2014). Fig. 2 shows that the graphite export prices from China to sample countries are much lower than the graphite products import prices from Japan to China. This indicates that China is suffering from a great disparity between export and import prices. The key reason is due to the current China's graphite trade structure, mainly exporting natural graphite resources and primary graphite products at low prices, while importing value-added graphite products at higher prices. China lacks advanced technologies and has to purchase value-added graphite products from developed countries, leading to a critical need to support graphite-related research activities. Unfortunately, due to domestic competition, many Chinese graphite resources exporters reduced their sales prices in order to receive international orders, making the related research activities less attractive (Yuan, 2008; Zhang et al., 2013; Yu, 2014).

3.3.4. EDR

There is a significant negative correlation between the graphite values and the EDR values. Fig. 3 shows the decreasing trend of the graphite EDRs. To be more specific, China cancelled the EDR of natural graphite since 2004. This was followed by the abolishment of EDRs on artificial graphite, colloidal or semi-colloidal graphite, graphite based products, non-electrical articles of graphite, and the reduction of EDR on refractory ceramic matters (>50% carbon) from 13% during 2005–2008 to 9% during 2009–2014. This means those graphite exporters have lost a large amount of tax benefits, making their export less attractive. Thus, the appropriate EDR policies can help restrict the overall export of graphite resources and support more value-added graphite businesses.

3.3.5. Language

Table 6 shows that the regression coefficient of language is 1.877510*** (significantly higher than 1%), which indicates that language can play a positive role in promoting China's graphite export. This may be because when the trade partners speak the same or similar language, both can save time and costs for translation (Chen, 2014). Therefore, the total trade cost is expected to decrease and the trade value is expected to increase, which is consistent with the prediction.

3.3.6. Economic recession

In Table 6, the regression coefficient of economic recession in the random effect model is 0.055899 (not significant), which shows that the effect of economic recession on graphite import isn't statistically significant. Although the graphite export volume decreased in 2008 and 2009 due to the impact of financial crisis (Yan, 2014; Yin, 2011), the overall export of China's graphite resource kept stable due to the rigid demand.

3.3.7. Political conflicts

The regression coefficient of political conflicts in the random effect model is −0.051313 (not significant), which indicates that the impact of political conflicts between China and the sample countries on China's graphite export isn't statistically significant. China

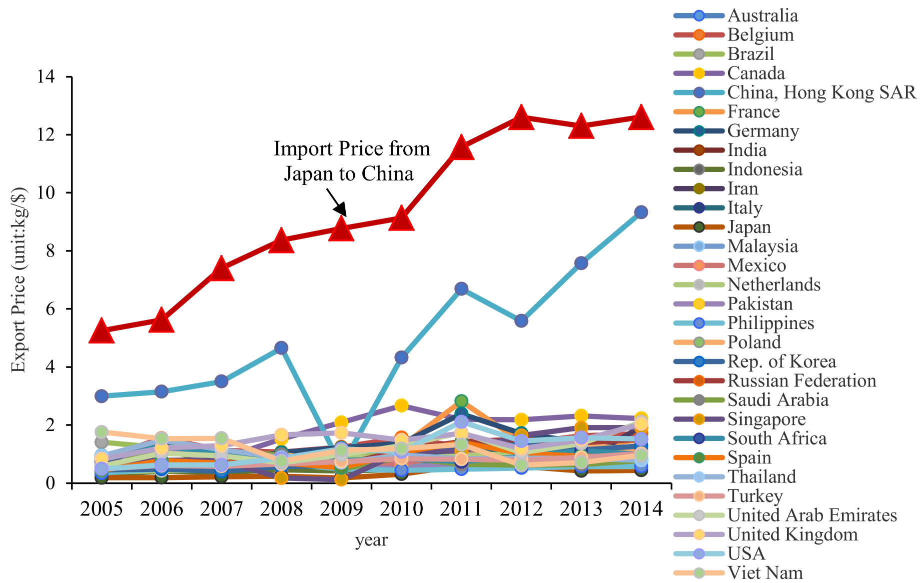

Fig. 2. The graphite export price from China to sample countries from 2005 to 2014.

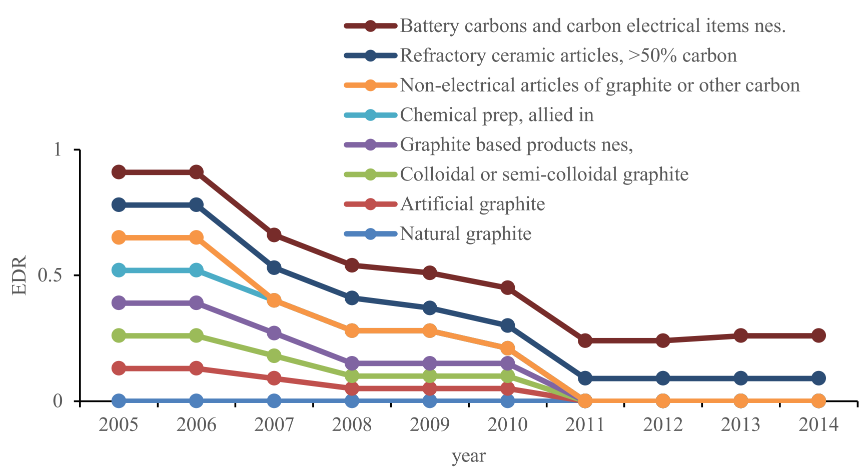

Fig. 3. The EDR values of China's graphite from 2005 to 2014.

kept good diplomatic relations with most of its trade partners.

4. Policy implications

The analytical results can help explain the effects of environmental regulations on China's graphite export. It is clear that great disparity between the export prices of China's graphite resources and the import prices of graphite products exists. Such a dilemma led to the depletion of natural graphite resources and corresponding environmental problems. It was predicted that China's current graphite resources will be depleted within 20 years under the current trend (Yan, 2014). In order to respond such a dilemma, various policies should be initiated so that all the related concerns can be appropriately addressed.

Firstly, policies that can facilitate technology innovation and transfer should be raised. The lack of advanced graphite production technologies is the key barrier for the Chinese graphite enterprises to further improve their processing abilities. The central government should allocate more research budget to support innovative technologies on graphite products (Zhang et al., 2013). All the relevant research organizations, including both universities and specific research institutes, should actively engage in it by encouraging their researchers to pay more attention on the relevant Call-for-Proposals. Besides this, international collaboration should be supported so that more advanced technologies and production equipment can be transferred from other developed countries. Plus, some leading enterprises should consider establishing their own funds for such research and development (R&D) efforts so that their special research demands can be quickly responded by the academia (Yin, 2011).

Secondly, a reasonable price mechanism on natural graphite resources should be set up. In order to increase the total export volumes, different enterprises tried to offer primary graphite products to their buyers with lower prices. Such irrational activities resulted in the overall lower prices for China's graphite resources and products in the international market. However, such lower prices did not internalize the environmental costs. Traditional economic accounting methods don't accurately reflect the true values of resources (Tao and Shen, 2013). Thus, the innovative pricing mechanism on graphite products should be established to reflect the whole life cycle values of such resources and products and incorporate these external costs into the final export prices.

Academically, emergy analysis is one feasible approach to uncover the true costs of environmental externalities although it will be more appropriate to combine it with life cycle assessment (LCA) (Geng et al., 2013, 2016). Therefore, emergy analysis method and LCA should be integrated to comprehensively and systematically measure the resources values including resource formation, mining, transportation, processing, waste disposal and environmental effect so that reasonable ecological compensation mechanism can be established. By doing so, appropriate export prices for graphite resource can be prepared. However, similar to other approaches, challenges remain and need to be solved by more research efforts, such as more accurate transformatives, more region-specific labor and service costs, etc. (Geng et al., 2014).

Thirdly, China's graphite resources management should be further improved. For instance, the abolishment of the natural graphite EDR has helped limit the graphite resources mining and products export. But more policies should be set up. In this regard, the Ministry of Land and Resources (MLR) should prepare more regulations on coordinating domestic graphite extraction and process industries so that the supply chain on graphite resources can be extended and more value-added graphite products can be produced within China. Also, it is critical to organize a national roundtable so that stakeholders on graphite resources can have an opportunity to share their concerns and discuss some common issues. Such a measure can help address different concerns from different parties and seek the potential solutions. It can also avoid irrational domestic competition and promote more cooperation among relevant enterprises. Finally, more capacity-building activities should be initiated so that all the stakeholders on graphite resources can improve their awareness and strengthen their coordination, such as regular workshops, pamphlets, website promotions, etc.

5. Conclusions

A large amount of graphite resources have been extracted in China and exported to other countries, leading to that its investigated graphite resources will be depleted within two decades if no innovative changes occur. Plus, the extraction and processing of graphite resources brought some environmental issues and public health concerns. In order to respond such a challenge, this study tries to uncover the historical trend and identify the quantitative relationship between China's graphite export values and environmental regulations by using the panel data of the top 30 countries that imported graphite from China for the period of 2005–2014. By using a random effect model, the results show that the economical mass, graphite export price, EDR and language are significant factors for China's graphite export values. Specifically, economical mass, export price and language have significantly positive correlation with the graphite export values, while there is a significantly negative correlation between EDR and the graphite export values. Moreover, the big gap between the import and export prices indicates that it's urgent for China's graphite enterprises to improve their technologies.

Due to the large amount of data processing, only the top 30 countries that imported graphite resources from China are selected as sample countries to investigate the effect of environmental regulations on China's graphite export. Thus the study results can't reflect the entire picture of China's graphite export. However, the total export amount to these sample countries is the majority of China's total graphite export amount, which makes the results quite representative.

In general, this study identifies the key factors on influencing China's graphite export by including price into the improved gravity model. Based upon the research findings, policy recommendations are raised, including more investment on relevant R&D efforts, the establishment of reasonable price mechanism and more innovative management measures (such as national industrial plan on graphite resources and processing, a national roundtable, and more capacity-building activities). These recommendations can help China improve its sustainable use of graphite resources. Research outcomes from this study can also provide valuable policy insights to other countries with similar challenges so that sustainable use of natural resources can be achieved.

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