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RESEARCH ARTICLE

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Do Environmental Regulations Influence the Competitiveness of Pollution-intensive Products?

Abstract According to "Pollution Haven Effect", in order to circumvent stringency environmental standards, dirty industries in developed countries will be chosen to locate into developing countries; another way is that developed countries increase imports of dirty products instead of producing by their own, both of which can contribute to the changes of comparative advantages in the past 30years. Since 1990s, many scholars have paid special attention on whether environmental regulations affect the trade patterns or not, but the conclusions are ambiguous. This paper, based on the Heckscher-Ohlin-Vanek (HOV) model and using respectively 95 and 42 countries sample data in year of 2005, is an empirical analysis which shows that: (1) according to the estimated results based on the "environmental governance" index calculated by CIESIN, environmental regulations do not change the comparative advantages of five types of pollution-intensive goods; (2) On the other hand, when the per capita income is considered as an endogenous indicator of environmental regulation, environmental regulation will significantly promote the comparative advantages in chemical products, iron and steel products and paper products, though environmental regulations do not take any influence on non-metallic minerals products and non-ferrous metals products. I believe that appropriate level of environmental regulation can promote a comparative advantage in pollution-intensive goods.

Keywords environmental regulation, pollution-intensive products, comparative advantages, trade patterns
JEL Classification F18, C31

The issues about trade and environment are multidimensional and intricate. A country's resource and environment can influence the production cost, trade pattern, factory location and gains from trade. Since the 1970s, these factors have been more and more important in international trade arenas because many industrialized countries began introducing significant control programs on environmental protection (Jayadevappa and Chhatre, 2000).

1 Introduction

In the past 30 years, tariffs in most countries of the world have been cut down greatly, and environmental

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regulations in industrialized countries, in this period, became more tighten. At the same time, world industry and trade patterns have been changing eventually—industrialized countries turning to produce clean goods instead of dirty goods which they have had competitiveness in the past. However, industrialized countries' consumption patterns did not changing according to their production patterns—consuming the import dirty goods, but did not need to endure pollution released form production any more. Some studies contribute such phenomenon to the stringent environmental regulations prevailed in developed countries since the late 1970s. Several issues triggered by environmental regulations can be traced to the Pollution Haven Hypothesis (PHH)[1] and the Pollution Haven Effect (PHE).

Under the free trade condition, the discrepancy in environmental regulations intensity as well as environmental regulations costs between the North and South countries are obvious. If the environmental endowment could influence trade flows completely, international division of labor can promote resources and pollutions to be re-distributed all around of the world. On this hypothesis, environmental regulations in one country may influence the environmental quality of another country. Therefore, do one country's environmental regulations influence its competitiveness of pollution-intensive products? And could such kind of competitiveness influence the trade patterns?

A lot of studies have specially paid more attention on whether environmental regulations influence the trade patterns since the 1990s (Tobey, 1990; Van Beers and Van den Bergh, 1997; Cole and Elliott, 2003a; Busse, 2004), but conclusions are ambiguous. Some studies also make literatures review on it, for example, Dean (1992); Van Beers and Van den Bergh (1996); Copeland and Taylor (2004), etc. In addition, because data used in these papers are outdated, and environmental regulations always have a lag influence on the trade patterns, then I use HOV model ever used in Leamer (1984) and Tobey (1990). By using exogenous and endogenous variable, I examine whether the environmental regulations influence competitiveness of pollution-intensive products or not. And I give preliminary interpretation to international division of labor in pollution-intensive industries.

The paper's structure as following: the second section is a literature review; in the third section, I try to make a clear definition on the pollution-intensive industries; in the forth section, I setup a HOV model used in many studies and show data specifications in this paper; the fifth section is the empirical results and analyzes; the last section are conclusions and shortcomings in my work.

2 Literature Review

According to the "pollution haven effect", stringent environmental regulations could increase the cost of pollution-intensive production. In order to circumvent domestic environmental standards, dirty industries in developed countries will be relocated in developing countries in which the environmental standards are not as strict as that of their own; alternative way for developed countries is to increase imports of dirty products instead of producing by their own. It shows the simple fact that international trade has a function to separate production and consumption in one region. If a country can consume pollution-intensive goods without enduring pollution and wastes released from production, under free trade conditions, international division of labor will tell us which country is lucky enough to have clean air and water. If so, environmental Kuznets curve hypothesis (EKC) may be a temporary phenomenon of international division of labor which will induce a worldwide reallocation of resources and pollution. Of course, all logic of this hypothesis is

[1] Copeland and Taylor (2004) distinguish between two different hypotheses linking pollution regulation to comparative advantage. The first is that a tightening up of pollution regulation will, at the margin, have an effect on plant location decisions and trade flows. They call this a pollution haven effect. The second hypothesis is that a reduction in trade barriers will lead to a shifting of pollution-intensive industry from countries with stringent regulations to countries with weaker regulations. They call this the pollution haven hypothesis. Based on this definition, our paper focuses on pollution haven effect.

still the principle of competitive advantage.

Modern international trade theories explain the country's competitiveness by diversity of countries' characteristics. Particularly, a country will own its competitive advantage by using its domestic abundant resource to produce.[2] In detail, because price of the country's abundant resource is relatively lower than that of the rare one's, those enterprises mainly depending on such abundant resource have cost advantages to compete with other enterprises which have to use the resource relatively rare in their countries. In an open economy, enterprises which use domestic abundant resource will expand their trade scale, otherwise, they will shrink the trade scale—this is just the nature of H-O theory. The competitive advantage in pollution-intensive commodities would arise from relative factor endowments, these are, labor, capital, natural resources, and the stringency of environmental regulations (Van Beers and der Bergh, 1996) [3] More specially, if a country is relatively well-endowed in terms of environmental resources (such as, more spaces absorbing pollution or more enduring on pollution) (Cagatay and Mihci, 2006), then with trade liberalization, lax environmental regulation (determined by the supply and demand of environmental endowments) could create a comparative advantage. Compared to other countries sharing the identical production, pollution and abatement style, the country with abundant endowments will have price advantage to do so (Dean, 1992). In theory, countries with lax environmental regulations (high environmental endowments) export pollution-intensive goods, while countries with stringent environmental regulations import it. In a lot of previous literatures, Levinson and Taylor (2008) demonstrate theoretically that there is a pollution haven effect in environmental regulations and trade patterns.

In general, there are two different methods to make an empirical analysis. The first method is based on natural endowments theory and HOV model (e.g., Tobey, 1990; Valluru and Peterson, 1997; Cole and Elliott, 2003a; Busse, 2004), and adds environmental regulation variables (environmental endowments) into labor endowments and capital endowments as joint variables by which scholars can demonstrate international trade flows. The second method employs gravitation model in international trade theory (e.g., Van Beers and Van den Bergh, 1997; Harris et al., 2002). Considering the relationship between environmental endowments and trade flows, I find the fist method is better.

Similar to Leamer (1984)'s method, Tobey (1990) used 11 endowments variables including environmental regulation calculated by Walter and Ugelow (1979) to investigate whether environmental regulations have influence on trade patterns or not. They found that during 1960s and 1970s, stringent environmental regulation has no any influence on the pollution-intensive industries' trade pattern of the 23 countries (only 10 freedoms in their estimation). However, as Cole and Elliott (2003a) state that "he does not find a statistically significant relationship between environmental regulations and net exports. Given the number of degrees of freedom, this is not entirely surprising". But this defect does not write off his initiative contribution on this field.

Based on HOV model, Valluru and Peterson (1997) focused on a sample of 40 countries in 1992. They evaluated those countries with net export of grain and its endowments including environmental regulation, so the relationship between environmental regulation and agricultural products trade flows can be made. The conclusion state that natural resource endowments can well explain grain trade pattern. But environmental regulation is not significant. Valluru and Peterson (1997) conclude that producers in grain export countries have no need to consider raising environmental regulations destroying their competitive

[2] International trade theories can be divided into two types: those emphasizing the importance of demand factors; and those focusing on supply factors. Two well-known supply-oriented theories are formalized in the Ricardian and the Heckscher-Ohlin models. However, interface between foreign trade and environmental quality seems to be predominantly regarded as a matter of supply factors. This justifies a closer look at the Heckscher-Ohlin (H-O) model (Van Beers and Van den Bergh, 1996).

[3] The degree of environmental regulation is endogenous by environmental endowments.

advantage on grain trade.

On the basis of HOV model, Cole and Elliott (2003a) used a cross section data of 60 countries in year 1995 to evaluate the effect of environmental regulation on trade patterns. They found that iron and steel industry and chemical industry have competitive advantages in countries with relatively well-endowed in terms of capital endowments resources; non-ferrous metals industry and paper and pulp industry have competitive advantages in those countries with relatively well-endowed in terms of mineral endowments and forest endowments resources. In the first condition, due to abundance of capital endowments in developed countries, strict environmental regulation cannot force iron and steel industries and chemical industries re-locate to developing countries in which the environmental regulation is lax, while in the second condition, the development of non-ferrous metals industry and paper and pulp industry are all dependent on the local resource endowments, therefore the two pollution industries' location to other countries are not occur. Cole and Elliott (2003a) is the first one to reveal that why environmental regulations have no capability to impact on the international trade flows. The most reasonable explanation is that there is a conflict between pollution haven hypothesis and factor endowments hypothesis (capital-labor effect).

Busse (2004) adopted a large size sample of 119 countries and five high pollution-intensive industries to analyze the relationship between trade and environmental regulations under the WTO framework. There are not sufficient evidences to support pollution haven effect except of iron and steel industry in which strict environmental regulation statistically negative on its net export. Busse (2004) also adopted per capita income of a country as the endogenous environmental regulation index in his analyses.[4]

So far, abundant empirical analyses do not give powerful support to the pollution haven effect—strict environmental regulation leads to the loss of competitive advantage in pollution-intensive industries. The reasons can be included as follows.

Firstly, Porter and Van der Linde (1995) put forward a theoretical viewpoint opposite to pollution haven hypothesis. They argued that a country with stringent environmental regulation can gain benefit from the improvement of domestic environmental quality, and bring up a competitive advantage in developing environmental industries. Therefore, the competitive advantages acquired in a long term can compensate short term loss of enterprise which could form a long term competitive advantage by such environmental regulation. Secondly, even in the short term, because of the interference of government, increasing stringency of domestic environmental regulations exerts a negative effect on export flows and a positive influence on import flows can be blurred, for instance, the negative impact of a relatively strict environmental policy on exports can be undermined by domestic subsidies to pollution-intensive industries (Van Beers and Van den Bergh, 1997). Apart from the above two reasons, there are also some defects in the empirical analysis. (1) The first one is endogenous problem of environmental regulation. Ederington and Minier (2003) argued that if environmental regulation is endogenous, then the discrepancy of environmental regulations among countries can obviously influence on trade patterns. (2) The cost of complying with environmental regulation is a relatively small fraction of total cost of production (Jaffe et al., 1995). If abatement costs are very small in comparison to other factors of production, there might be no

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4 We can get references in these four literatures. (1) Too small size of sample will conduct estimate bias; (2) Due to environmental regulations can produce obviously influence on pollution-intensive industries' exports, most studies adopted pollution industries and pollution products in their analyses, but there is no means that in other industries having no any relationship between environmental regulation and trade patterns; (3) There are obvious discrepancy in the degree and consequence by which environmental regulation bring to different pollution industries, so we ought to classify the pollution-intensive industries by their inherent characteristic; (4) the availability and quality of environmental regulation's data affect on the empirical results directly, one method to solve the problem is to make per income as endogenous environmental regulation.

clear influence of environmental regulations on trade pattern (Antweiler, et al., 2001). Usually, total abatement costs do not exceed 4% of total costs (Busse, 2004). (3) Cave and Blomquist (2008) stated that the lack of empirical evidence can not due to the above two factors, but the measurement of pollution-intensive industries in literatures is the key problem.

Besides, even if pollution haven effect exists, factors affecting on the trade pattern of pollution-intensive commodities are not merely the discrepancy of environmental regulations, but also determined by other competitiveness in commodities (such as, other factor endowments). In such conditions, if the strength of traditional competitiveness exceeds over its environmental competitiveness, the countries with stringent environmental regulation may still export pollution-intensive goods (Ederington, 2007). There are two kinds of explanations on it.

Firstly, it shows that relatively strict environmental regulations have a strong impact on trade and factory location choice in case of 'footloose' industries, however, such an effect is less dominant in the case of industries that are strongly linked to a country due to the (unique) availability of specific inputs such as resource materials (Van Beers and Van den Bergh, 1997; Harris et al., 2002). Because specific inputs are hard to be substituted, dirty industries can not readily be located into other places and the trade patterns does not change any more.

Secondly, the opposing forces of the KLH (capital-labor hypothesis) and PHH may explain why the empirical literature finds the best mixed results (Antweiler et al., 2001; Cole and Elliott, 2003b; Elliott and Shimamoto, 2008). According to factor endowments theory, a capital-abundant country would export capital-intensive commodities, while a labor-abundant country would export labor-intensive commodities. However, capital-intensive sectors are also typically pollution-intensive sectors, yet capital-abundant countries are typically those with some of the highest environmental regulations. Specially, the KLH implies that the capital-abundant North countries will specialize in capital-intensive production, while the labor-abundant South countries will do the opposite. In contrast, the PHH implies that the low regulation South countries will specialize in pollution-intensive production, while the North countries do the opposite. So the opposing forces above two factors may lead the empirical results mix (Elliott and Shimamoto, 2008).

3 Pollution-intensive Industries

In literatures, there are two main measurements to define the dirty industries. The first measurement is to estimate the pollution intensity of product, that is calculate the emissions released from per unit of production. The second method is to measures the pollution content by using of pollution abatement and control expenditures (PACE), which captures the producer's cost burden of pollution regulation (Akbostanci et al., 2007).

Low (1992) calculated relative abatement costs for US industries, and according to Low's calculation, Busse (2004) classified the dirty industries, which is abatement costs of at least 1.8% of total costs, including: industrial chemicals industry, paper and pulp industry, non-metallic minerals industry, iron and steels industry, and non-ferrous metals industry. In this paper, I also adopt the five kinds of dirty industries in Busse (2004). Because resource-based industries (non-footloose industries) could not be relocated into other places easily, the influence brought by environmental regulations to the competitiveness of these industries is uncertain. Consequently, in this paper, I also adopt UNIDO (1982) classification standards for resource-based industries and footloose industries, so dirty industries can be classified into two parts. Table 1 shows the five kind of high pollution-intensive industries and corresponding SITC code.

Table 1 Pollution-intensive Industries and Corresponding SITC Code

Industries	SITC Code	Commodity specification	Resource category
Industrial chemicals	51	Organic chemicals	RB
	52	Inorganic chemicals	RB
	562	Manufactured fertilizers	RB
	59	Other chemical material and products	NRB
Paper and pulp	251	Paper and waste paper	RB
	641	Paper and paperboard	RB
	642	Articles of cut paper and board	RB
Non-metallic minerals	66	Non-metallic mineral manufactures	RB
Iron and steel	67	Iron and steel	NRB
Non-ferrous metals	681	Silver and platinum	RB
	682	Copper	RB
	683	Nickel	RB
	685	Lead	RB
	686	Zinc	RB
	687	Tin	RB
	689	Other non-ferrous base metal	RB

Note: Busse's (2004) selection of industries is based on Low's (1992) calculations. SITC Rev.3; selection of resource category is based on UNIDO (1982). RB means resource-based commodities, NRB means footloose commodities.

4 HOV Model and Data Specification

Despite the conceptual problems with the assumptions on which the Heckscher–Ohlin model is based, differences in resource endowments seem to explain trade patterns surprisingly well (Valluru and Peterson, 1997). HOV model is a multi-country, multi-commodity, and multi-factor model based on the H-O model introduced by Vanek in 1968. HOV is a variant version of traditional H-O model, or we can say it is a factor content version of H-O model. Compared with the H-O model, HOV model does not need to define relative factor abundance in different countries and relative factor intensity in different kinds of commodities, therefore, it can directly be extend to m (commodity)$\times n$ (factor), (m, $n>2$). The most important contribution of HOV model is that it merely regards of international trade of goods as production factor endowments exchange among trading countries. This changing viewpoint makes a big influence on the latter empirical works. Among many literatures, Leamer (1984) gives us a specification form to test the resources of international competitiveness, so we can see as follows:

$$N_{it} = C_{io} + b_{i1}V_{1t} + b_{i2}V_{2t} + \ldots + b_{i11}V_{11t} + u_{it} \quad (1)$$

where N_{it} stands for net exports of each of the five classified commodities (i) in country t, C_{io} is a constant term, V_{kt} stands for all kinds of endowments (k) in country t (k=1, …, 11). Leamer (1984) takes capital, labor (professional or technical workers, literate non-professional workers and illiterate workers), land (rainy-tropical land, dry land, humid meso-thermal land and humid micro-thermal land), coal, minerals, and oil as endowments of resource in a country. Based on Leamer (1984), Tobey (1990) adds environmental regulation D_{Et} (1–7, such as 1 stands for relax environmental regulation; 7 stands for stringent environmental regulation) to test whether the discrepancy of environmental regulation can affect on the competitiveness of dirty goods or not.

In order to estimate HOV model, net export data, factor endowments data, and environmental regulation data should be found firstly. According to available data, I use cross section data of year 2005 to estimate. Besides, only 42 countries' labor index classified by educational degree, therefore this paper adopts a sample of 95 countries which labor variable is classified as aggregation to regress; and a sub-sample of 42 countries which labor variable is divided into three groups by educational degree.

Table 2 Trade Patterns of Pollution-Intensive Commodities: 2005

1	2	3	4	5	Countries
−	−	−	−	−	US, New Zealand, Korea, Greece, Hungary, Estonia, Latvia, Uruguay, Costa Rica, Ecuador, Panama
+	−	−	−	−	Ireland, Morocco, Switzerland
−	+	−	−	−	Slovenia
−	−	+	−	−	China, Czech Republic, Iran, Italy, Portugal, Spain, Turkey
−	−	−	+	−	Argentina, France, Rumania, Britain
−	−	−	−	+	Australia, Sri Lanka, Peru
+	−	−	+	−	Netherlands, Ukraine
−	+	−	−	+	Norway
−	−	+	−	+	Mexico, Philippines, Poland
+	−	+	+	−	Japan
+	−	−	+	+	Bulgaria
−	+	+	+	−	Austria, Slovakia
−	+	−	+	+	Sweden
+	−	+	+	+	Russia
−	+	+	+	+	Finland

Note: 1: Industrial chemicals; 2: Paper and pulp; 3: Non-metallic minerals; 4: Iron and steel; 5: Non-ferrous metals.

(1) Net exports: according to the classification of pollution-intensive industries in Table 1, we classify the trade data in corresponding five kinds of dirty goods. The value of net exports of all five commodities (Nit) (unit: US dollar) including industrial chemicals (CHE), paper and pulp (PAP), non-metallic minerals (NMM), iron and steels (IAS), and non-ferrous metals (NFM) is regarded as dependent variables. Data comes from UN COMTRADE (2007). In order to describe the trade pattern distinctly, I show the distribution of net export of dirty commodities of 42 countries in detail, "＋" stands for positive value of net export, "－" stands for negative value of net export (Table 2). And Fig. 1 also shows the distribution of each dirty industry (unit: 100 million US dollar). Vertical axis stands for the value of net export.

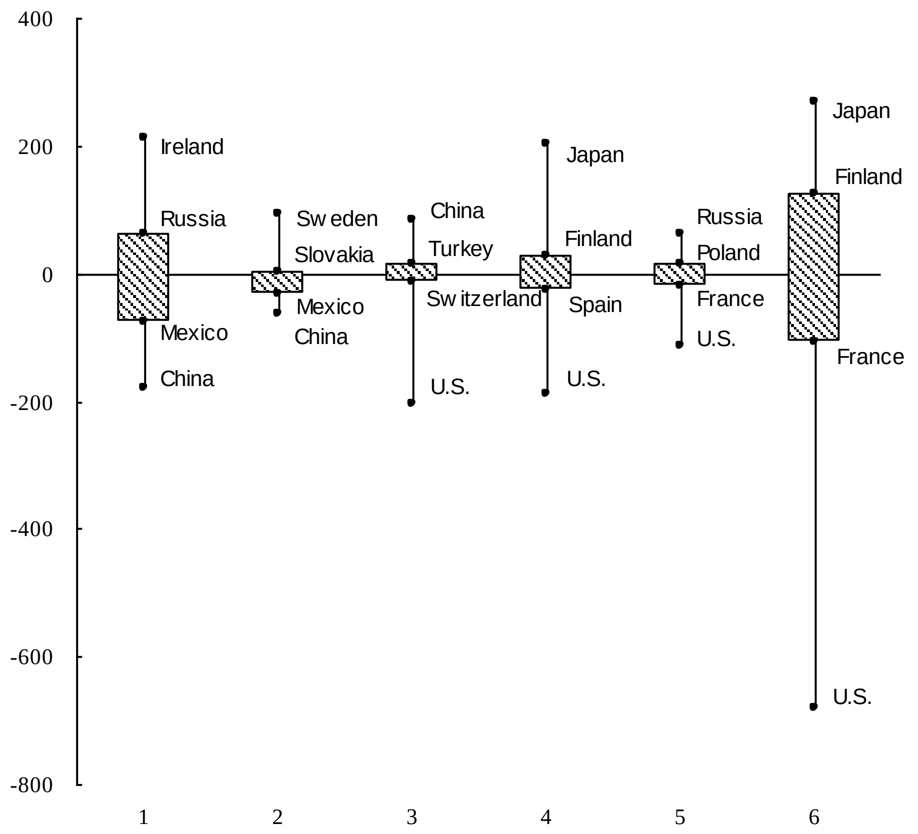

Fig. 1 Distribution of Pollution-intensive Commodities in 42 Countries or Regions: 2005

Note: Based on imports and exports data in database of UN COMTRADE, 1 stands for net exports of industrial chemicals; 2 stands for net exports of paper and pulp; 3 stands for net exports of non-metallic minerals; 4 stands for net exports of iron and steel; 5 stands for net exports of non-ferrous metals; 6 stands for net exports of aggregate dirty goods.

(2) Due to the data of capital stock (CAP) are not available directly, I need to calculate it by using other index. Therefore, I select the method used by Leamer (1984), and cross section data are of 2005. The raw data comes from world development indicators (WDI) in the *world bank 2007*. On the basis of gross capital formation (2000 constant price, unit: US dollar) flows from 1991 to 2005,[5] and assuming an average life of 15 years which is consistent with Leamer (1984) and Tobey (1990), the discount rate is 13.3%. However, some of developed countries (Austria, Denmark, Finland, Germany, Greece, Ireland, Italy, Portugal, Spain, and Switzerland) do not provide the gross capital formation index, but these countries have a relatively high importance in my sample, then it can be approximately substituted for gross fixed capital formation index. Therefore, the formulation for capital stock as follows:

$$K_{it}^{b} = \sum_{j=0}^{t} (1-\delta)^{t-j} I_{ij}$$

where t stands for year 2005; I_{ij} stands for gross capital formation of country i in time j (j = 0, 1, ..., 14); δ stands for discount rate of capital (13.3%). K_{it}^{b} stands for total capital stock of country i in year 2005 (2000 constant price).

(3) According to the different analyses in the paper, I adopt total labor force data and labor force

5 Gross capital formation index is known as gross domestic investment (GDI) in WDI database.

divided by educational degree published by WDI in 2005. The later specification for labor force can help us distinguish human capital from common labor force. According to the discrepancy of educational degree, labor force can be divided into three categories: number of workers classified as tertiary education (Lab1); number of workers classified as secondary education (Lab2); number of workers classified as primary education (Lab3).[6]The three indexes are all given by a percentage formation in WDI database. Therefore, I let labor force data be multiplied by the above three percentage, the absolute value (unit: per person) can be acquired.

(4) Land (LAND) data and forest (FORE) data represent land endowment in this paper. These two indexes are obtained from WDI database. The unit is square kilometer.[7]

(5) Leamer (1984) takes the values on production of coal and oil (including natural gas) as independent variables separately. In this paper, I adopt value of production of coal (COAL), oil and natural gas (OIL) data, and add above two data together as a country's energy endowment (ENER). Data all come from country's energy balances table in International Energy Agency in 2005. These data are all conversed into the equivalence heat of oil (unit: kiloton).

(6) Common minerals are aluminite, copper, fluorite, iron ore, lead, manganese, nickel, potassium, pyrite, salt, tin, and zinc. Leamer (1984) adds all value of production of minerals mentioned above as the one to be a representative index of mineral. Here I choose the most important mineral resource which is the value of production of copper, iron ore, lead, and zinc as the representative of mineral.[8] The four mineral data provided by US Geological Survey 2005. The unit for iron ore is kiloton; and the unit of other three minerals is ton. Due to the distribution of world mineral resource is uneven, making every mineral resource as separate independent variables will cut down the power of explanation in model. So the four quantities of mineral are multiplied by its spot price, and then added up, the value of production of mineral resource (MINE) index (unit: US dollar) are acquired.

(7) Because the data on the environmental variables are generally not available, many empirical studies are hard to carry out (Xu, 2000; Busse, 2004).[9] This paper uses environmental sustainability index provided by the Centre for International Earth Science Information Network (CIESIN) for 146 countries, in which the environmental governance index is calculated by a series of 12 variables. Busse (2004) adopted environmental governance index in CIESIN (2003) as a representative index of environmental regulation. Because this index covers a comprehensive country, this paper will also adopt environmental governance index in CIESIN (2005) as one of environmental regulation variables. Besides, the correlation between per capita income of a country and the degree of environmental regulation is very high (Dasgupta, 2001). Xu

[6] Leamer (1984) uses cross section data of year 1958 and 1975. It is consistent with the historical condition by using the illiterate rate as the criterion to distinguish common labor force. However, this method cannot measure common labor force correctly in current condition. For most countries, there are endogenous correlations between employment and educational degree, or in other words, illiterate workers could not get jobs.

[7] Leamer (1984) distinguishes land endowment into four categories to analyze whether land endowments have contributions to net exports of agriculture. But the correlation between net exports of pollution-intensive commodities and land endowment is low. So I adopt total land data as land endowment variable in this paper.

[8] In the estimation of Busse (2004) and Cole and Elliott (2003a), they respectively use these four kinds of mineral resources as independent variables.

[9] In order to measure the environmental stringency of countries, Walter and Ugelow (1979) firstly collect the information obtained from a questionnaire prepared by UN COMTRADE in 23 countries and build an "environmental stringency index" which measures countries' degree of environmental regulation and ranks countries from 1 (strict) to 7 (tolerant). Quoting data from Walter and Ugelow (1979), Tobey (1990) gives an analysis on a country's environmental stringency and its trade patterns. Consequently, Dasgupta (2001) develops indices of environmental policy and performance for 31 countries by using a quantified analysis of reports prepared by the United Nations Conference on Environment and Development (UNCED). Besides, Van Beers and Van den Bergh (1997) construct the environmental regulations' strictness measure for 21 countries in OECD, which is consistent with "polluter paying principle". However, the above methods have a common defect that is limitation for sample countries. So in multiple regressions, small size of sample may reduce validity of estimation and restrict study scope.

(2000), for example, illustrates that correlation coefficients between the environmental stringency index and ICPGDP, and between the environmental stringency index and PCGNP are 0.86987 and 0.8553, respectively. Both are significant at 1% level. This means that environmental stringency is determined by endogeneity. Such as environmental stringency in ACT (Antweiler et al., 2001) model is an endogenous variable, and determined by income and price. Therefore, this paper adopts another representative environmental regulation index, per capita income (GNI), as an endogenous variable. Data source is also WDI database.

The correlation coefficients of variables should be calculated before estimating (because of length limitation of this paper, the table of correlation coefficient of variables do not be reported here). The value of correlation coefficient can clearly show that there is a high correlation relationship between land and forest, the value is 0.94. By contrast, land variable is more explanative than forest variable in the model; therefore, land variable is taken as the land endowment in this model. At the same time, coal is more sensitive than oil in estimating equation, but when we consider the characteristic of energy, I adopt energy variable (including coal variable and oil variable) as the independent variable in the model. The correlation between land variable, energy variable, and mineral variable are significant and the coefficient is very high. Adopting these variables in the model will bring multicollinearity in estimation. However, considering the economy meaning of these variables, I continue adopt these variables in model' specification. Besides, there is a high degree of correlation between a country's environmental stringency and its per capita income, it is shown that the correlation coefficient between environmental governance provided by CIESIN (2005) and per capita income is very high, and the coefficient is 0.79, which is statistically significant at the 1% level.

According to above analysis, the model's specification is setting as follows:

$$N_{it} = C_{io} + b_{i1}CAP_{1t} + b_{i2}LAB_{2t} + b_{i3}LAND_{3t} + b_{i4}ENER_{4t} + b_{i5}MINE_{5t} + b_{i6}D_{6t} + u_{it} \quad (2)$$

$$N_{it} = C_{io} + b_{i1}CAP_{1t} + b_{i2}LAB1_{2t} + b_{i3}LAB2_{3t} + b_{i4}LAB3_{4t} + b_{i5}LAND_{5t} + b_{i6}ENER_{6t} + b_{i7}MINE_{7t} + b_{i8}D_{8t} + u_{it} \quad (3)$$

I use model (2) as the equation to be estimated by sample 1 (including 95 countries), and use model (3) as the equation to be estimated by sample 2 (including 42 countries), which, N_{it} stands for net exports of pollution-intensive commodity *i* in country *t*. *CAP* stands for capital stock; *LAB*1, *LAB*2, and *LAB*3 individually stands for tertiary educational labor force, secondary educational labor force, and primary educational labor force; *LAND* stands for land area; *ENER* stands for energy; *MINE* stands for mineral resource; *D* stands for environmental regulation variable which includes exogenous environmental regulation (*REGU*) and endogenous environmental regulation (*GNI*) (statistical characteristic of variables in the model is not be reported here).

5 Empirical Results

In analysis, I take net exports of total pollution-intensive industries (*TOT*) as the dependent variable in sample 1 (including 95 countries) and sample 2 (including 42 countries), and take production factor endowments as independent variables. I use OLS method to estimate the multi-factor regression (because of length limitation of this paper, the all estimated results do not be reported here). The results in sample 1 and sample 2 are very similar. The significant negative relationship between capital stock and net exports of pollution-intensive commodities tells that if a country is relatively well-endowed in terms of capital stock could be a net import country for pollution-intensive commodities. I use a country's land area to stands for the degree of abundance of natural resource. The result shows that there is a statistically significant positive relationship between land areas and net exports of dirty commodities. As a conclusion, if a country is relatively well-endowed in terms of land (means well-endowed in natural resource) could be a net export country for pollution-intensive commodities. In energy analysis, a statistically significant negative relationship between energy endowments and net exports of pollution-intensive goods tells that energy inputs are acquired in dirty goods production. The relationship between mineral resource and net exports in pollution-intensive industries is also negative, but results in sample 1 and 2 are slightly different, which the negative effect in sample 2 is more significant than that of sample 1. If we pay more attention on sample 1 and 2, we can also find that endogenous environmental regulation (*GNI*) and exogenous environmental regulation (*REGU*) have positive related with the total net exports in dirty industries, which means that stringency of environment regulation does not reduce competitiveness of net exports of pollution-intensive commodities in one country, whereas the country has advantages in promoting exports in pollution-intensive industries. In sample 1, total labor endowment is not obviously responsible for the net exports of dirty commodities. The interesting counterpart finding is that there is positive relationship between human capital (*LAB*1) or common labor force (*LAB*2) and total dirty commodities' net exports in sample 2. If we want to interpret results simply by analyzing the total pollution-intensive industries, we have no capability to determine correctly signs of factor endowments influenced by net exports of dirty commodities. Therefore, it is necessary for us to analyze the five different pollution-intensive industries one by one.

In the following analysis, I use sample 2's data (including 42 countries), and net exports of industrial chemicals (CHE), paper and pulp (PAP), non-metallic minerals (NMM), iron and steels (IAS), and non-ferrous metals (NFM) as dependent variables, the results are reported in Table 3.

The relationship between capital stock and net exports in pollution-intensive industries is negative. Before we add environmental regulation variable into the equation (see Model 1 in Table 3), four kinds of dirty industries do not show significant relationship between capital endowment and net exports, except for non-ferrous metals industry. There is a significant negative relationship between capital endowment and net exports in the non-ferrous metals. When environmental regulation variable is estimated in equation, the results also show the negative relationship between capital endowment and net exports in industrial of chemicals and iron and steels. The result obviously shows that increasing capital stock can't increase net export of dirty commodities in one country. According to the discrepancy on degrees of capitalized labor force, labor endowments can bring different effects to net exports of dirty goods: Before we add environmental regulation variable into the regression equation, only human capital variable (R&D) in non-metallic minerals industry clearly shows significant negative sign in the model. When we add the environmental regulation variable into the model, human capital in the industrial chemicals industry and iron and steels industry give us significant positive signs in the model; the "t" statistics of human capital variable in paper and pulp industry and non-ferrous metals industry have been improved dramatically. However, equations also show negative signs in non-metallic minerals industry. According to the results, if a country is relatively well-endowed in terms of human capital could be a net export country for industrial chemicals commodities and iron and steels commodities. If endogenous environmental regulation variable is added into the model, human capital endowment is also a competitive factor increasing paper and pulp's export. Similar with the above analysis, secondary educational labor force does not show any explanation or show a significant negative sign in the model. Therefore, secondary educational labor force cannot become a competitiveness factor in the export of five dirty industries. However, common labor force can greatly promote the exports of non-metallic minerals, iron and steels, and non-ferrous metals as results show, so I put the common labor force into the origin of one's competitiveness in the three kinds of dirty good as mention above.

Table 3 Results of HOV Model: 42 Countries

Variables	industrial chemicals (*CHE*)			paper and pulp (*PAP*)			non-metallic minerals (*NMM*)			iron and steels (*IAS*)			non-ferrous metals (*NFM*)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
C	1.9E+09	3.0E+07	–3.8E+08	10E+08[c]	–8.5E+06	–16E+06	–2.2E+08	–5.0E+08	–3.8E+08	5.2E+08	–1.3E+09	–1.1E+09	1.9E+08	–2.9E+08	–1.2E+08
	(1.68)	(0.02)	(–0.25)	(1.75)	(–0.01)	(–0.02)	(–0.69)	(–1.00)	(–0.84)	(0.53)	(–0.90)	(–0.86)	(0.71)	(–0.68)	(–0.33)
CAP	–1.7E–03	–3.3E–03[c]	–3.8E–03[b]	–5.2E–04	–1.4E–03	–1.5E–03	1.9E–04	–4.9E–05	5.0E–05	–1.4E–03	–3.0E–03[c]	–2.9E–03[c]	–1.3E–03[a]	–1.8E–03[a]	–1.6E–03[a]
	(–1.07)	(–1.71)	(–2.16)	(–0.67)	(–1.45)	(–1.64)	(0.45)	(–0.09)	(0.10)	(–1.05)	(–1.84)	(–1.90)	(–3.61)	(–3.82)	(–3.71)
LAB1	456.9	689.1[c]	797.9[b]	173.6	296.8	323.7[c]	–279.6[a]	–245.1[b]	–256.5[b]	367.4	594.4[c]	609.1[b]	91.2	150.2[c]	138.1
	(1.43)	(1.93)	(2.35)	(1.09)	(1.68)	(1.89)	(–3.15)	(–2.42)	(–2.54)	(1.35)	(1.98)	(2.07)	(1.19)	(1.77)	(1.62)
LAB2	–628.7[a]	–652.5[a]	–662.0[a]	–202.8[c]	–215.4[c]	–217.4[c]	107.4	103.9	105.2	–337.7[c]	–360.9[c]	–361.2[c]	–116.3[b]	–122.3[b]	–120.9[b]
	(–2.74)	(–2.88)	(–3.05)	(–1.78)	(–1.92)	(–1.98)	(1.69)	(1.62)	(1.63)	(–1.73)	(–1.89)	(–1.91)	(–2.12)	(–2.26)	(–2.21)
LAB3	–12.6	131.1	111.2	–83.9	–7.7	–29.4	142.1[a]	163.5[a]	150.5[a]	266.3[b]	406.7[a]	354.0[a]	76.1[b]	112.6[a]	93.1[b]
	(–0.09)	(0.76)	(0.77)	(–1.20)	(–0.09)	(–0.41)	(3.65)	(3.34)	(3.53)	(2.24)	(2.81)	(2.84)	(2.27)	(2.74)	(2.58)
LAND	818.0	513.8	604.3	399.9	238.5	305.8	1065.5[a]	1020.3[a]	1051.0[a]	2520.1[a]	2222.7[a]	2368.6[a]	371.3[c]	294.0	341.9
	(0.93)	(0.57)	(0.72)	(0.91)	(0.54)	(0.72)	(4.35)	(4.02)	(4.22)	(3.37)	(2.95)	(3.25)	(1.76)	(1.38)	(1.62)
ENER	–4489.3	–3833.6	–8633.9	–5390.3	–5042.6	–7214.1	–8211.1[b]	–8113.7[b]	–8491.6[b]	–27978[a]	–27337[a]	–30915[a]	–320.7	–154.0	–890.5
	(–0.40)	(–0.35)	(–0.81)	(–0.97)	(–0.92)	(–1.33)	(–2.65)	(–2.59)	(–2.67)	(–2.95)	(–2.95)	(–3.32)	(–0.12)	(–0.06)	(–0.33)
MINE	–0.7	–0.6	–0.6	–0.2	–0.1	–0.2	–0.6[a]	–0.6[a]	–0.6[a]	–1.2[b]	–1.0[c]	–1.1[c]	0.1	0.2	0.1
	(–1.13)	(–0.83)	(–0.97)	(–0.68)	(–0.36)	(–0.52)	(–3.22)	(–2.97)	(–3.12)	(–2.15)	(–1.81)	(–2.03)	(0.72)	(1.03)	(0.84)
REGU	—	2.4E+09	—	—	1.3E+09	—	—	3.6E+08	—	—	2.4E+09	—	—	6.2E+08	—
		(1.39)			(1.49)			(0.73)			(1.62)			(1.49)	
GNI	—	—	118297[b]	—	—	52054.8[c]	—	—	8006.7	—	—	83836.8[c]	—	—	16263.9
			(2.22)			(1.93)			(0.51)			(1.81)			(1.22)
R^2	0.291	0.331	0.386	0.276	0.323	0.352	0.880	0.882	0.881	0.532	0.568	0.576	0.810	0.822	0.818

Note: *t*-statistics in parentheses; "a" denotes significance at the 1 percent level; "b" denotes significance at the 5 percent level; "c" denotes significance at the 10 percent level.

The more instructive conclusion is that land endowment is another origin of competitiveness in non-metallic minerals, iron and steels, and non-ferrous metals. The reasonable explanation is that country which is well-endowed in terms of land area would also a country rich in natural resource. Whereas energy endowment and mineral endowment do not increase export of dirty goods as land does. Specially, in non-metallic minerals industry and iron and steels industry, there are significant negative relationship between energy endowment (and mineral endowment) and net exports makes us believe many differences existing in different industries. My interpretation is that exports in these two industries not also depend on imports of abundant resource, e.g., iron ores but also rely on a great deal of energy in production.

The stringency of exogenous environmental regulation (*REGU*) does not give any influence on the competitiveness in dirty industries. According to the results, exogenous environmental regulation variable is insignificant in the model. But it is very interesting for us that endogenous environmental regulation (*GNI*) can promote exports of these three kind of dirty commodities (industrial chemicals, paper and pulp, and iron and steels), or we could say that environmental regulation has become an origin of export competitiveness in the three industries, because it shows significant positive sign in the model. However, except for non-metallic minerals product and non-ferrous metals product, endogenous environmental regulation does not give any influence on the trade patterns. We interpret it by that the above two kinds of commodities are resource-based products. As mentioned in literatures, when industry is limited by using specific resource inputs in resource-based dirty commodities production, increasing the stringency of environmental regulation can’t influence the trade pattern easily.

Based on the analysis mentioned above, we can clearly find that competitiveness in chemicals product and paper and pulp product comes from human capital (R&D); that of non-metallic minerals products are derived from common labor force endowment and land endowment; competitiveness of iron and steels products comes from human capital endowment, common labor force endowment, and land endowment; that of non-ferrous metals products come from common labor force endowment.

Because dependent variables (net exports of five dirty commodities) in Table 3 are classified by two-digit code of SITC Rev.3, it is obviously heterogeneous in different commodities in the same category. For example, pearl and jewel (667) and lime and cement (661) are all belonged to trade item 66, but quantities of pollutants released from them are much different, or we can say that quantities of pollutants released from per unit value of production are different. To keep homogeneous in commodities, I use net exports of dirty commodities classified by three-digit code in SITC Rev.3 as dependant variables and use factor endowments as independent variables. We think that method of cross-section panel data in estimation is sound (because of length limitation of this paper, the all estimated results are not reported here). The result shows that the statistic levels and estimation signs of factor endowment variables in the model are consistent with Table 3. Under such condition, there also exists significant positive relationship between endogenous environmental regulation and net exports of three pollution-intensive commodities (chemicals product, paper and pulp product, and iron and steels product). Simultaneously, the estimation coefficient of endogenous environmental regulation and non-metallic minerals product (and non-ferrous metals product) is not significant. We also find that there is a significant positive relationship between environmental regulation reported by CIESIN (2005) and net exports of iron and steels products, except that the exogenous environmental regulation is not significantly responsible for the trade flows of the other four kinds of dirty commodities. Generally speaking, the results are so similar in three-digit trade code and two-digit trade code that the signs and “t” statistic of independent variables are not changed either. Iron and steels products are the exception which the significant positive relationship exits between exogenous environmental stringency and net exports of iron and steels, which shows us that increasing the stringency of environmental regulation would increase net exports of iron and steels products. This conclusion contradicts the Busse (2004) who found the significant negative relationship between environmental stringency and net exports of iron and steels products.

According to the analysis, I conclude that (1) if a country’ main endowment is common labor force, the country will has competitive advantages in exporting non-metallic minerals products and non-ferrous metals products which belong to resource-based pollution-intensive commodities. What’s more, environmental regulation can’t take any effects on the net exports of these two kinds of dirty commodities in sample. The reason is that firms in resource-based industries often choose resource-abundant countries as their factory location. Therefore, a country would not decrease exports volume when pollution abatement costs are increasing. (2) If a country is well-endowed in terms of human capital are usually own competitive advantages in exporting industrial chemicals products, paper and pulp products, and iron and steels products. Environmental stringency (endogenous variable determined by income level) can increase the net exports of such three dirty commodities. This conclusion is different with Tobey (1990), Cole and Elliott (2003a), and Busse (2004).

In fact, developed countries with income advantages still retain the export advantage in dirty commodities, especially in high additional value commodities. Increases environmental stringency would generate the international trade invention and develop some abatement technologis for a long run (Porter and Van der Linde, 1995). At the same time, relatively stringent environmental regulations have negative effect on export flows, which can be cut down by subsiding pollution-intensive industries; however, a country with stringent environmental regulation usually sets import restrictions to foreign products which hardly meet the higher domestic environmental standards, this kind of environmental barrier called a secondary trade barrier. This effect will offset the influence on net export induced by the discrepancy of environmental endowments. Under the two trends, stringent environmental regulation can promote the net exports of industrial chemicals products, paper and pulp products, and iron and steels products. However, due to restrictions on the specific factor inputs, net exports of non-metallic minerals products and non-ferrous metals products are hard to be influenced by environmental regulations. Though paper and pulp products also depend on the input of specific factors (woods), forest resource belongs to renewable resource, stringent environmental regulation can reserve and increase resource endowments, fatherly, promote the net export of resource-based dirty commodities in paper and pulp products.

6 Conclusion and Discussion

By using a sample of 95 countries and a sub-sample of 42 countries in 2005, I adopt HOV model in international trade theory and a method of cross section panel data to test the different effects on the competitiveness of pollution-intensive commodities by introducing two different environmental regulations. The empirical results shown as follows:

(1) Competitiveness in pollution-intensive commodities has the same characteristics as that of traditional factor endowments'. Firstly, except for paper and pulp products, human capital endowment is the origin of competitiveness of pollution-intensive commodities in footloose industries; and common labor force endowment becomes the origin of competitiveness of dirty goods in non-footloose industries. Secondly, capital endowment does not increase a country's competitiveness in dirty commodities. The probable reason is that the direction of capital flow has changed in last ten years—the capital flows from pollution-intensive sector to clean goods sector. However, only by the empirical analysis in this paper, we can't clearly confirm whether environmental regulation leads to the changing of capital flows.

(2) The empirical results in this paper does not find any evidence on the issue which states that increasing environmental stringency would cut down the competitiveness in dirty commodities; on the contrary, strict environmental regulation can promote some dirty commodities' (industrial chemicals products, iron and steels products, and paper and pulp products) competitive advantages in export. Specifically, when the environmental governance index in CIESIN (2005) is adopted as exogenous environmental regulation variable, the environmental regulation does not significantly influence the direction of net exports in five kinds of dirty commodities. But when I use endogenous environmental regulation, represented by per capita income, to test, stringency environmental regulation does increase the competitiveness of two items of dirty commodities (industrial chemicals and iron and steels products) in footloose industry, and increase one item of dirty commodities' competitiveness (paper and pulp products) in non-footloose sector. This conclusion is obviously different with Tobey (1990)'s. However, at the other end, this conclusion is consistent with Porter and Van der Linde (1995)'s view—environmental regulation can promote the competitive advantage in pollution-intensive commodities. But we cannot give the conclusion that environmental regulation spurs the creation of pollution abatement technologies by merely using empirical analysis in this paper.

We need to concern more on two different environmental regulation effects on the resource-based dirty commodities (non-metallic minerals products, non-ferrous metals products, and paper and pulp products): due to the limitation of specific resource, endogenous environmental regulation does not influence the net exports of non-metallic minerals products and non-ferrous metals products. This conclusion is same as Cole and Elliott (2003a)'s. In addition, except for in the production of paper and pulp products, strict environmental regulation will obviously promote exports of such kind of resource-based dirty commodities. We find that exports of non-metallic minerals products and non-ferrous metals products depend on input of non-renewable resource. A country with stringent environmental regulation (or high environmental cost) usually invest a lot of fund to reserve forest or other natural resources, so the country will own more forest resource, and become an exporter in paper and pulp. However, in the non-renewable resource aspect, environmental regulation can only constrain to the quantity of exploiting not as well as to increase resource endowment.

(3) A country with abundant human capital and strict environmental regulation will has competitiveness in the export of footloose dirty commodities. Generally speaking, rich countries can meet this condition; on the contrary, a country with abundant common labor force and non-renewable resource will come to build competitiveness by exporting resource-based dirty commodities—poor countries always meet such condition. Therefore South-North trade pattern in dirty commodities would gradually emerge. Under such condition, the effect of international trade on a country's environmental quality is dependent on the stage of economic development and the changes of comparative advantages. With the changes of economic development stage and comparative advantages, Pollution Heavens maybe transfer all around the world.

(4) As the paper shows, the country, wanting to improve the pollution-intensive commodities' competitiveness, should concern on the country's human capital accumulation and environmental regulation. A country can't win any competitiveness by destroying its environmental quality. On the contrary, acquiring the chance of economic growth by destroying environmental quality will undermine the country's competitiveness. This means that it's inappropriate and groundless for a government to hope to achieve the economic growth goals and win the comparative advantages in pollution-intensive commodities by loosen its environmental regulations. And I ought to highlight that it's not real to make a same standard in global environmental regulations. The rational and equitable decision for a country is to set up a proper environmental regulation consistent with its development stages (or income level). Chinese government ought to strengthen environmental administration, encourage its' firms to adopt advanced pollution abatement equipment and support enterprises to introduce pollution abatement technologies into production, and provide necessary financial support or other favorable economic policies to firms by which help them meet environmental standards to the best of one's ability.

There are also some shortcomings in my paper: firstly, the high correlation relationship between environmental regulation and per capita income in real life make some estimation not correct enough. Secondly, some hypothesis in the HOV model can't satisfy terms of the real economy. For example, (a) one hypothesis in HOV model assumes that the enterprises share the same technologies when enterprises produce same commodities, but in fact, countries have different technology in producing the same product; (b) HOV model hypothesize that the world has no transportation cost and trade barriers. The reality is that there are many transportation costs and trade barriers in international trade, though tariff has decreased greatly. If there is confliction between transportation *geography* and environmental regulation *geography*, the environmental regulation effects on the trade pattern would be greatly cut down; (c) HOV model also needs perfect market, constant return to scale, no externality and public goods. In the real world, these conditions are hard to be found. Besides, pollution abatement costs in developed countries are more than these of developing countries', so dirty industries in developing countries may become 'clean' in the condition of they are located in developed countries, vice versa. This is so-called endogenous pollution abatement cost mentioned by Cave and Blomquist (2008). I prefer call it "pollution intensity reversal" as the same nature of 'factor intensity reversal' in international trade theory. This problem could lead to bias in estimation. At last, this paper is only the first step of my recent work. The problems I mentioned above will constitute a further study in the future.

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