The impact of trade liberalization on the environment in some East Asian countries: an empirical study

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Abstract

We examine a cross- country data set of 6 East Asian countries[2] for the period of 1980-2006 with the aim to study the interrelationship between trade liberalization and environmental degradation. On the basis of the parametric econometric model, we investigate trade liberalization's impact on the environment quality[3]. In this paper, we chose two environmental indicators for analysis that are carbon dioxide (CO2) emissions from the consumption of energy and primary energy consumption. On the basis of the parametric model, we investigate linear, heteroscedasticity and autocorrelation in the environmental degradation. We first try to investigate the existence of an Environment Kuznets Curve (EKC) to depict the interrelation between per capita income and the environment quality, and then determinants influence the environment in the process of trade liberalization and globalization.

We found no evidence for the existence of an EKC for the relation between per capita income and environmental indicators of carbon dioxide and energy consumption. The evidence is supportive for the pollution heaven hypothesis and indicates that the more liberalization in trade would increase carbon dioxide emissions and the level of energy consumption in these countries in East Asia. There is also an evidence support the monotonically increasing linear trend between per capita income and both pollutants. Further insightful studies on the relation between trade liberalization and environmental quality are needed in order to make sound environmental policies for developing countries.

JEL classification: F18, Q56, C33, O11, O13

Keywords: EKC, trade liberalization, pollution, economic growth, income

[2] They include China, Indonesia, Malaysia, Philippines, Thailand and Vietnam

[3] Environmental quality is a term of wide comprehension that relates to natural environment and built environment, such as air and water pollution, noise, hazardous waste, solid waste, recycling, deforestation, climate change, energy consumption, etc. In particular, air pollution consists of many pollutants, such as sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO2), volatile organic compounds (VOCs), Chlorofluorocarbons (CFCs), Ammonia NH3), etc.

Introduction

The growing literature has been investigated the relationship between economic development and the environment quality which becomes more important to economic and environmental policy- making. Debates have been widely taken place with regards to some environmental problems such as the Environmental Kuznets Curve (EKC), pollution heaven hypothesis, "race to the bottom" hypothesis, the factors endowment hypothesis, and industry relocation hypothesis, etc. The EKC hypothesis, which depict a reduced form or an inverted –U shape relationships between environmental degradation and economic growth, indicating that the pollution level rises as a country develops, but environment becomes cleaner on average as the economy develops further and rising incomes pass beyond a turning point, creates conflicting issues and much debates. Under the EKC hypothesis, environmental policy plays a vital role in reducing the negative impacts of economic activities on the environmental quality.

Since the early 1990s, many empirical studies have been examined the relationship between income, trade liberalization and pollution in different development stages, using cross-country and time series data. Different econometric methods have been applied to investigate this relationship, including nonlinear and linear parametric models, semi parametric and non parametric models, etc. However, evidences on the relationship between trade liberalization and environment are conflict, particularly for developing countries. There are quite few empirical evidences for the effects of trade liberalization on sustainable development. The existence of EKC depends mainly on types of pollutants, countries and time studies, types of data- time series or cross-country data. We try to estimate and provide a robust empirical evidence for the interrelations between trade liberalization and environmental degradation. This study also tries to examine whether or not trade liberalization would improve environmental quality in developing countries in East Asia.

Trade liberalization is considered as raising national incomes and reduced in trade barriers[4]. As reduction in trade barriers, trade rise rapidly, but the environmental problems can be either alleviated or exacerbates by the inefficient environmental regulation, however to what extent it depends on the comparative advantage, strict environmental regulation, and the type of policy instrument. If environmental policy is considered as an endogenous factor, then increases liberalization could reduce emission, but the effects of welfare are not clear

[4] Prior to trade liberalization, there are two kinds of distortions, namely trade barriers and inefficient environmental regulations.

1. Trade liberalization and the environment: A theoretical overview

Many empirical studies have been examined the relationship between income, trade liberalization and pollution in different development stages, using cross- country and time series data. It possibly exists an inverted U- shaped relationship between income and pollution- namely EKC, which has been attracted much attention (Grossman and Krueger 1993 and 1995, Shafik and Bandyopadhyay 1992, Shafik 1994, Selden and Song 1994, Suri and Chapman 1998, Jean Agras and Nuane Chapman 1999, and Matthew A. Cole 2004; Theophile Azomahou, Francois Laisney and Phu Nguyen Van 2006; Phu Nguyen Van and Theophile Azomahou 2007). Some argued that the EKC should be interpreted with care because of the fragile EKC and weakness of its concept (Arrow et al., 1995, Ekins 1997, Stern and Common 2001).

The skepticisms for most empirical studies concentrate on few pollutants such as sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), energy consumption, etc, and the other pollutants have their own relations with income, not the same for all; The empirical results can be influenced significantly by research methods, time of studies, samples, cross-country or time series data; the impacts of economic growth on the pollutions depend on the source of economic growth. The others tried to take into account the effects of trade liberalization on pollution; trade liberalization reduces pollution (Antweiler et al 2001), whereas Dasgupta et al (2002) find that trade liberalization does not affect positively on the environment in the developing countries.

The pollution heaven hypothesis (PHH), which was supported by the studies of some authors (Suri and Chapman 1998, Mani and Wheeler 1998). The PHH bases on the differences in environmental stringent regulations between the North and the South[5], therefore the South has a comparative advantage in pollution intensive production while the North specializes in clean production. The South provides pollution intensive products for the North via trade. This is the channel that pollution transfers from the North to the South. Whereas some authors (Grossman and Krueger 1993, Gale and Mendez 1998) find evidence against the PHH, but support for the factor endowment hypothesis (FEH).

The findings of evidences consistent with the PHH are quite mixed. A number of studies investigate the environmental consequences of trade liberalization, or the impacts of income and economic growth on the environment (Janicke et al 1997; Mani and Wheeler 1998, A. Cole

[5] The North implies developed countries while the South refers to developing countries

2004). However, few studies assess the net trade effects on environment or on an indicator of sustainable development. UNEP (1999) finds evidence support trade liberalization having a negative impact on sustainable development in various developing countries. Whereas the UNEP's study (2001) shows that trade has a positive effect on sustainable development in several developing countries.

A lot of literature has provided potential interactions between international trade and the environment quality (Grossman and Krueger 1992, 1995; Shafik and Boandyopadhyay 1992; Copeland and Taylor 1994; Cole 2000 and 2004; Copeland and Taylor 2003). Trade liberalization makes countries cope with greater competitive pressure, thus they will use resources more efficient, and consequently, pollution emissions decrease; Trade liberalization through free trade agreements (FTA) and WTO promote technical and environmental standards so that countries may restraint imports of environmental damaged goods.

First Grossman and Krueger (1995), and then Copeland and Taylor (1994 and 2003) denoted three different channels through which economic growth influences the environmental quality[6] and shapes the EKC, they are *the scale effect, the composition and technique effects*. The scale effect indicates the increase of pollution resulting from economic growth and growing market access. The composition effect implies changes in structure of an economy, as a consequence of trade liberalization, the economy specializes growingly in activities that she has a comparative advantage. The technique effect refers to the use of cleaner technique of production that goes with trade liberalization. As income growth, the income- induced demand leads to cleaner environmental regulations, higher environmental standards and environmental protection, and access to friendly environment techniques of production. The composition effect is the channel through which the pollution heaven hypothesis would have impacts on pollution. However, to what extent and how the composition effect having impacts on pollution depends on the comparative advantage of a country.

Most empirical studies used parametric specification such as cubic or quadratic polynomials to examine the relations between environmental quality and per capita income, and

[6] Grossman and Krueger (1993) also decomposed the effects of trade and foreign investment liberalization on the environment into three different channels: scale, composition and technique effects, the same the growth- environment relation.

to test the inverted U- shape[7] hypothesis of the EKC. Some studies investigated both the inverted U- shape hypothesis and the N- shape hypothesis for developed countries (Bruyn, Van den Bergh and Opschoor 1998; Angela Canas, Paulo Ferrao and Pedro Conceicao 2003). The effect of trade liberalization on the environment has been discussed in a number of papers (Suri and Chapman 1998; Antweiler et al 2001; Copeland and Taylor 2003; Cole 2004). The evidences are mixed, whether trade liberalization having positive or negative effects on the environment depend on sources of comparative advantage, environmental regulations, and the pattern of trade[8].

An empirical study applied parametric and semi parametric models to examine the relationship between the deforestation process and per capita income and the level of openness and some other explanatory variables. However, the study did not provide an evidence for the existence of an EKC. Trade liberalization did not affect positively to the deforestation process (Phu Nguyen Van and Theophile Azomahou 2007).

The pollution heaven hypothesis (PHH) states that if a country has comparative advantages in weak environmental regulation or enforcement, then the trade- composition effect will affect negatively to the environment in this country[9], because it will shift to specialize in the most pollution intensive production. The PHH also indicate that poor countries may specialize in the most pollution intensive sectors because of their comparative advantages. In other words, suppose all countries having the similar relative factor endowment, then richer countries will impose a more stringent environmental regulations and this will make them specialize in clean goods.

By contrast, the factor endowments hypothesis states that the source of comparative advantage lies in factor abundance and technology, environmental regulation does not affect or affect little on the trade pattern. Following this view, capital abundant countries have a comparative advantage in capital intensive productions which are considered more polluting

[7] Authors such as Grossman and Krueger (1995), Shafik (1994) found evidence for the N-shape of EKC which implies that as economic activities enlarge rapidly, the negative impact of the scale effect is always larger than the positive impact of the other two effects- composition and technique.

[8] The standard Heckscher-Ohlin model indicates that free trade makes a country with environment abundance specialize increasingly in pollution intensive goods. However, Stolper- Samuelson theorem shows that as the price for the use of environment is more expensive, techniques of friendly environment production can be used.

[9] In this hypothesis, countries with weak environmental regulations are low-income ones.

than labor intensive productions (Mani and Wheeler 1998; Antweiler et al 2001). If this is the case, then developing countries should specialize in labor intensive sectors while developed countries specialize in capital intensive sectors. Therefore, in practice, specialization is not necessarily consistent with the factor abundance, but whether or not factor abundance and environmental regulation difference affect trade patterns depend on which factor is stronger.

The "race to the bottom" hypothesis indicates that coping with the pressure of international competition for foreign direct investment (FDI), countries tend to lower environmental standards and regulations. This race would lead countries to a lowest common environmental standard. Being affected by the international trade and competition pressures, imports of goods from abroad, which is considered as an alternative abatement mechanism, make pollution demand become more elastic and responsive to policy's changes.

2. Data and Variables

2.1 Dependent environmental variables: carbon dioxide emissions from the consumption of energy and primary energy consumption

We tested the cross- country sample of 6 countries in East Asian[10], for the period of 1980-2006. Two distinct pollutants have been chosen as environmental variables: per capita carbon dioxide emissions from the consumption of energy (hereafter carbon dioxide, CO2) and per capita primary energy consumption (hereinafter energy consumption). These countries are the newly- industrialized economies and rapid growing, consuming a large amount of energy and generating a large amount of pollutions, including carbon dioxide and other toxic gas. We chose these six countries in East Asian for this study because they took a large amount of energy consumption (about 60% energy consumption by all non- OECD Asian countries, EIA data 2008). Primary energy consumption is produced air pollutions which led to polluted environment, the depletion of natural resources and climate change. Moreover, energy consumption plays an important role keeping these countries a rapid growth.

Two distinct pollution indicators are selected: per capita primary energy consumption and per capita carbon dioxide emissions from the consumption of energy. Per capita primary energy consumption is measured in quadrillion (10^{15}) British thermal units (Btu), from the source of the Energy Information Administration (EIA), 2008. Per capita primary energy consumption is

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[10] They include China, Indonesia, Malaysia, Philippines, Thailand and Vietnam. Indonesia, Malaysia, Philippines, Thailand and China are the second generation of newly industrialized economies (NIEs2). Vietnam, to some extent, is considered as NIEs3.

considered as a pollutant. Per capita carbon dioxide emissions from the consumption of energy are calculated in metric tons of carbon dioxide per person, from the Energy Information Administration (EIA), 2008.

2.2 Explanatory variables

The interactions between the quality of environment and economic variables may be very dimensional. Many studies tried to capture these dimensions and to do comprehensive studies on the relation between economic growth and the environment. However, due to the lack of monitoring and data on environmental pollution in developing countries, therefore this study aims at capturing impacts of economic growth and trade liberalization on the environment.

2.2.1 Per capita GDP

Per capita GDP is measured in constant 2000 US Dollars as income measure, and the data comes from the World Development Indicators (WDI) 2008. This variable is used to measure interactions between incomes and pollutions. We used a quadratic functional form for the per capita income variable because the quadratic functional form permits to check an inverted- U shape relationship between the dependent and explanatory variables or an EKC. The cubic term, which allows us to examine the second turning point, may not be appropriated for the newly industrialized and developing economies. Figure 1 presents the relation between carbon dioxide and per capita GDP; Figure 4 depicts the relation between energy consumption and per capita GDP.

Many debates on the relationship between environmental quality and per capita income have been taken recently. The results, to some extent, aided to fill up the literature gap concerning the role of economic and environmental policies to improve the quality of life. These debates also emphasize in finding evidences for the existence of an EKC for environmental quality. Indeed, the EKC has been found for some environmental pollutants such as sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), primary energy consumption, suspended particles, deforestation, .., etc.

The existence of EKC is a necessary condition for improving environmental quality. The important sufficient condition is to implement appropriated economic and environmental policies for the protection of environment and sustainable development. If an EKC exists, then a turning point for the EKC is estimated as the equation (1) of ($-b_1/2b_2$). An EKC would differ and exist for some incomes ranges. If there is no evidence for the existence of an EKC, we can skip this step.

2.2.2 The growth rate of GDP

GDP growth rate is calculated in percentage changes and coming from the WDI 2008. This variable is used for measuring impacts of economic growth on pollutions. The rapid growth is necessary to improve human well-being on a sustainable basis. However, rapid growth itself is not sufficient for the improvement of environmental quality. Environmental protection policy and economic policies need to be coordinated to converse rapid growth to the improvement of well- being and environmental quality.

2.2.3 Level of openness

Trade intensity or the level of openness as a percentage of GDP is measured as a share of the sum of exports (X) and imports (M) of goods and services in GDP ((X+M)/GDP); This data is calculated on the basis of data coming from the WDI 2008. Level of openness is considered as an indicator to measure the level of trade liberalization, trade openness and integration's level to the World economy. This variable aims at capturing effects of trade liberalization and openness to the World economy on the environmental quality. Some authors, such as Grossman and Krueger (1992), Shafik and Bandyopadhyay (1992), Jean Agras and Duane Chapman (1999), and Phu Nguyen Van, Theophile Azomahou (2007),... etc, used this indicator to estimate the impact of trade openness on the environmental quality. Figure 2 presents the relation between carbon dioxide and the level of openness; figure 5 depicts the relation between energy consumption and the level of openness.

Trade has the important contribution to economic and environmental performances in developing countries. As the international trade theory indicates that poor countries have advantages in labor and natural resource intensive products while rich countries have advantages in capital intensive products. Through trade, rich countries could relocate their polluted industries and shift polluted products to poor countries where environmental standards are always low and loose. Therefore, the environment seems to clean in the rich countries, but degrade in the poor countries.

The variable of trade should reflect clearly the pollution heaven hypothesis and factors endowment hypothesis, if one of these hypotheses is right. Following the pollution heaven hypothesis, the trade coefficient must be positive for poor countries (and negative for rich countries, if any). According to the Factors endowment hypothesis, if dirty industries are capital intensive and rich countries are regarded as capital abundant, then the trade coefficient must be negative for poor countries (and positive for rich countries, if any).

2.2.4 *Foreign direct investment (FDI)*

FDI data comes from the WDI 2008 and is measured in percentage as the total net foreign direct investment (FDI) in current US dollars in a year divided by the GDP in current US dollars in that same year (net FDI/ GDP). We used data on net FDI for the purpose of decrease in autocorrelation and disturbance for this variable[11]. This variable tries to estimate FDI's impacts on pollutions in the context of trade liberalization. Figure 3 depicts the relation between carbon dioxide and foreign direct investment; figure 6 presents the relation between energy consumption and foreign direct investment.

As environmental theory indicates that rich countries would shift their polluted industries to poor countries because governments of rich countries raised environmental standards and as a result, rich countries lost the advantages in these industries. Poor countries, which have low environmental standards, are destinations for polluted industries from rich countries through FDI. Moreover, poor countries compete with each others to attract FDI to meet the capital demands for economic development. The intensive competition of FDI attraction would make poor countries lower environmental standards and as a consequence, lead to the "race to the bottom" in environmental standards

2.2.5 *Population density*

Population density is estimated base on the data from the WDI 2008 and measured in people per square kilometer. This variable is computed as the total numbers of population at year t divided by the surface area at year t (Pop/ S). In reality, an increase in population density would make environment degrade. The higher population density is, the higher probability the environment becomes more polluted. Therefore, we chose the population density as an explanatory variable in order to measure impacts of an increase in population on pollutions. Table 1 shows descriptive statistics for dependent and explanatory variables.

3. Econometric model

The environmental Kuznets curves (EKC) is a "reduced- form" relationship, in which the level of pollution is estimated as a function of per capita income. The advantage of the reduced-form approach is that it provides the net effect of income per capita on pollution. The econometric specification is based on the following model. Trade and FDI are included in this EKC framework, and then the modifier model is estimated for two environmental variables.

[11] If data on accumulated FDI is made use, the probability of autocorrelation for this variable is high.

$$Y_{it} = bo + b1x_{it} + b2x_{it}^2 + az_{it} + \mu_i + \varepsilon_{it}, \quad (1)$$

Where y is the level of pollution being tested; x is per capita income; z is a matrix of explanatory variables including GDP growth rate, trade intensity or level of openness, FDI, and population density; b0 is the intercept, μ_i is country- specific effects and would be fixed or random, and ε_{it} is error term; Subscripts i and t represent country and year respectively. Data for this model is balanced cross- country panel[12].

Equation (1) allows us to test for various forms of economic and environmental relationships. If $b_1 > 0$ and $b_2 = 0$ presents a monotonically increasing linear trend, meaning that rising income accompanies by rising level of pollution and energy consumption; If $b_1 < 0$ and $b_2 = 0$ presents a monotonically decreasing linear trend, indicating the reversal relationship between income and environmental indicators; If $b_1 > 0$ and $b_2 < 0$ indicates an EKC; If $b_1 > 0$ and $b_2 > 0$ presents a U- shape relation that we do not expect.

Grossman and Krueger (1995) mention three different channels where economic growth affects the environmental quality: the scale effect, the composition and technique effects. As income grows, income elasticity towards the environment also grows, therefore the public requires prudent governmental regulations on the environmental quality and firms tend to use cleaner technique for productions. Reaching a threshold income level, countries tend to give more priority for the protection and higher standards of environment.

The basic EKC models is a simple reduced-form quadratic function, recently studies seem to deal with a cubic function[13]. For having the inverted- U shape from the above mentioned function, it needs b_1 to be positive and b_2 to be negative. In the standard Heckscher - Ohlin model, the overall use of the environment does not change; and trade liberalization is neutral for the environment.

However, Trade liberalization, association with the environmental externalities, makes countries specialize in pollution- intensive goods in environment- abundant countries. According to the Stolper- Samuelson theorem, the price to be paid for the use of environment tends to

[12] On the basis of earlier studies, aspects of a country that either do not change or change very slowly over time are controlled for by including country specific fixed effects. Random effect is calculated for time- varying omitted variables and stochastic shocks that are common to all countries.

[13] Grossman and Krueger 1995, Shafik 1994 found evidence of an N-shape curve. This means that the negative scale effect is bigger than the positive composition and technique effects because the economic activity enlarges.

increase as externalities internalized, firms adjust to less pollution- intensive techniques for production. For the wealthier countries, 75% of all technology transfers come from foreign trade (OECD 1995); for the developing countries, if trade liberalization raises real income, then the effects of income may reduce pollution because citizens may demand for a cleaner environment, thus the technique effect would be positive for the environment.

4. The environmental Kuznets curve (EKC)

We suppose y_{it} be the dependent pollutant variable (carbon dioxide and energy consumption) of country i, i= 1,…,N in year t, t=1,…,T; x_{it} is the level of real per capita GDP of country i at year t; and z_{it} is the matrix (p×1) vector of the other explanatory variables. Firstly, we test the existence of an environmental Kuznets curve (EKC). Secondly, we study determinants for pollutants through examining the functional forms between independent pollutant variables and the explicative variable of per capita GDP and testing the statistical hypothesis. The nonlinear and linear functional forms were checked for the purpose of finding the most fitted functional form for our data. For simplicity, we investigate a general parametric model below:

$$Y_{it} = bo + b1x_{it} + b2x^2_{it} + \mu_i + \varepsilon_{it}\,, \quad (2)$$

Where μ_i, which is country- specific effects, would be fixed or random[14]; ε_{it} is the error term, and b0, b1 and b2 are parameters that are needed to be estimated.

The quadratic functional form in X is taken to test some nonlinearity in the relationship between pollutants and per capita GDP. For the existence of an EKC, the necessary condition is to exist the nonlinear functional form in the pollutants- per capita GDP relations; and the sufficient condition is that the parameter of the equation (1): $b1 > 0$ and $b2 < 0$. If the necessary and sufficient conditions are met, an EKC exists.

We apply the Fisher test for both pollutants: carbon dioxide and energy consumption. For carbon dioxide, the hypothesis Ho is that the quadratic term is null, resulted in $F(1, 154) = 1.99$, greater the critical value of F (0.1602), but not statistical significance at 10% level. Therefore, we cannot reject the null hypothesis of the quadratic term. For energy consumption, we took the same F test as for carbon dioxide, results were similar to the F test for carbon dioxide: F (1,

[14] We estimate the fixed effect models by the fixed effect within regression and random effect by the generalized least square (GLS) regression.

154) = 1.99, higher than the critical value of F (0.1607), but not statistical significance at the 10% level. Hence, we accept the null hypothesis of the quadratic term.

We take the test for the hypothesis of linearity in the function form, which represents the positive results at 5% statistic significant level. For carbon dioxide, the F test for the hypothesis that the linear term is null, resulted in F (1, 151) =887.92, far greater than the critical value of statistic F (0.00) at the 1% significant level, thus we can reject the null hypothesis. For energy consumption, we take the F test for the hypothesis of the null linear term, resulted in F (1, 151) = 981.17, far greater than the critical value of F (0.00) at the 1% significant level. Hence, we can conclude that our data for carbon dioxide and energy consumption is most fitted for the linear functional form.

The fixed and random effect specification for carbon dioxide resulted in b1 > 0 and b2 < 0, meeting the necessary condition for the existence of an EKC. However, the data does not fit the nonlinear functional form. The data for energy consumption does not meet the necessary condition with the results of b1 > 0 and b2 > 0. The data is most fitted for the linear functional form. Therefore, we can conclude that there is no evidence for the existence of an EKC for pollutants of carbon dioxide and energy consumption, and our data is most fitted the linear functional form.

5. Determinants of pollutants

As indicate above, the linear functional form is most fitted for our data, thus we have a modified version of the equation (1)

$$Y_{it} = bo + b1x_{it} + az_{it} + \mu_i + \varepsilon_{it}, \quad (3)$$

Where z_{it} is a matrix (p×1) vector of the other explanatory variables, including the growth rate of GDP, trade intensity, foreign direct investment (FDI) and population density.

Firstly, We estimate the Fisher test for the null hypothesis of non significant conjoint explanatory variables in the presence of significant conjoin explanatory variables for carbon dioxide and energy consumption respectively, resulted in F (5, 151) = 548.32, and F (5, 151) = 699.87, far greater than the critical values of F (0.00) at 1% significant level. Thus, we reject the null hypothesis and conclude that the explanatory variables are significant conjoint.

Secondly, we compute the F test for the null hypothesis of homogeneity in the presence of heterogeneity. The results indicate that we can reject the null hypothesis because the statistic F (5, 151) =284.49 for carbon dioxide and F (5, 151) = 204.93 for energy consumption, higher than the critical values (0.00) at the 1% significant level. Thus, our data is in favor of heterogeneous model. In other words, the fixed country effect model is preferred.

Thirdly, we compute the F test for the null hypothesis of random country effect specification against the alternative fixed country effect specification for carbon dioxide. The Hausman value of χ^2 (4) = 14.19 is higher than the critical value of Hausman statistic test (0.0067) at the 5% significant level. The probability of test is lower than 10% significant level. Therefore, we can reject the null hypothesis. The fixed country effect model is preferable to the random country effect model for carbon dioxide. Estimation for the fixed country effect for carbon dioxide is reported in table 2. Estimate results indicate that per capita GDP, GDP growth and trade are significant statistics and have significant positive impact on carbon dioxide. However, we need to test heteroscedasticity and autocorrelation of errors before accepting these results.

For energy consumption, the Hausman statistic test[15] result with χ^2 (4) = -33.47. This can be interpreted as a strong evidence to indicate that we can accept the null hypothesis. Hence, the random effect model is preferable for energy consumption. Specification for random country effect is reported in table 3. Estimate results show that per capita GDP, GDP growth and FDI are significant statistics. However, we also need to check heteroscedasticity and autocorrelation before confirming these results.

Fourthly, we also take some necessary tests to find models that are most fitted our data. We test the normality of residual. As presents in most econometric works, the error is supposed to follow the law of normal distribution N (0, σ^2). The results for the tests of normality in residual are that $\chi^2(2)$ = 12.37, higher than the critical value (0.0021) at the 5% significant level for carbon dioxide and energy consumption. Thus, we can conclude that the error term follow the law of normal distribution.

[15] In case the probability of the Hausman test is greater than the critical value at the over 10% significant level. The Hausman test cannot differentiate between the fixed effect model and the random effect model.

We take the test of Breusch- Pagan for the null hypothesis of homoscedasticity[16], resulted in $\chi^2(1) = 630.56$ for carbon dioxide and $\chi^2(1) = 603.72$ for energy consumption, both larger than the critical value (0.00) at the 1% significant level. The Breusch- Pagan test indicates that we can reject the null hypothesis and accept the alternative heteroscedasticity[17]. It also shows that the random effects are totally significant at the 1% significant level.

Now we take the test of autocorrelation of errors with AR (1) disturbance. The statistic value for the F-test is that F (5, 145) = 37.60, higher than the critical value (0.00) at the 5% significant level. Thus, we can reject the hypothesis Ho of absent autocorrelation errors for carbon dioxide. We take a further test of Durbin- Watson for the absent autocorrelation. The observed value of Durbin- Watson = 0.46, lower than the value[18] tabulated lower bound (1.458). Hence, we can reject the null hypothesis of absent autocorrelation errors in favor of the hypothesis positive first- order autocorrelation for carbon dioxide.

For energy consumption, the value of statistic F (5, 145) = 17.66, higher than the critical value (0.00) at the 5% significant. The Durbin- Watson statistic value = 0.5802, lower than the value tabulated lower bound (1.458) in the table[19] at the 1% significant level. Therefore, we can conclude that there exists the positive first- order autocorrelation for energy consumption.

In short, we have taken the different tests for different model for determining the best estimators and the most fitted functional form for our data. On the basis of these tests, we can conclude that the fixed country effect model with autocorrelation and heteroscedasticity across panels is determinant for carbon dioxide; for energy consumption, the random effect model with autocorrelation and heteroscedasticity is determinant. We also correct the autocorrelation of errors in these two models. In order to fit the panel data linear model with autocorrelation and heteroscedasticity, we apply the feasible generalized least squares (FGLS) to correct

[16] In statistic, a sequence or a vector of random variables is homoscedastic if all random variables in the sequence or vector have the same finite variance. This is also known as homogeneity of variance. The complementary notion is called heteroscedasticity. (Wikipedia)

[17] In statistic, a sequence or a vector of random variables is heteroscedastic, if the random variables have different variances. In contrast, a sequence of random variables is called homoscedastic if it has constant variance. (Wikipedia)

[18] The value in the table of Durbin- Watson is that the lower bound dL = 1.458 and the upper bound dU = 1.799

[19] See 3

heteroscedasticity and autocorrelation structure to correct autocorrelation of errors within panels and cross- sectional correlation. This method allows us to estimate an adjust matrix of variance-covariance of errors in the presence of heteroscedasticity and autocorrelation.

6. Empirical results

Estimation results for carbon dioxide with the correction of heteroscedasticity and autocorrelation (table 4) indicate that the variables of per capita GDP, trade and population density are statistical significant, while the variables of GDP growth rate and FDI and the intercept are not significant. The results imply that per capita GDP, trade and population density have positive significant effects on carbon dioxide. The positive effect of population density is not consistent with our arguments. The choice of population density in urban area as an explanatory variable would be more appropriate.

Per capita GDP and trade have significant impacts on carbon dioxide. The coefficient of per capita GDP is greater than zero, indicating a monotonically increasing linear trend which implies that a rise in income accompanies by an increase in the level of carbon dioxide. This would cause concerns for the governments in developing countries for the improvement of human well- being and the protection of environment. Thus, it needs further in- depth studies on the income – carbon dioxide relations for making this relation more clear.

The positive trade coefficient implies the increasing linear trend between the level of openness and carbon dioxide. This is an evidence support the pollution heaven hypothesis, implying the poor countries are destinations for polluted industries from rich countries, and the more liberalization in trade the more increase in carbon dioxide. Therefore, further in- depth studies on the trade liberalization’s impacts on carbon dioxide and the role of economic and environmental policies should be conducted.

Estimation results for energy consumption with the correction of heteroscedasticity and autocorrelation (table 5) also indicate that three variables of per capita GDP, trade and population density are statistical significant. Similar to the case of carbon dioxide, the positive coefficient of per capita GDP supports a monotonically increasing linear trend between energy consumption and per capita GDP. This is consistent with arguments support the linear trend for the relation between energy consumption and per capita income (Suri and Chapman 1998). The negative coefficient of population density is inconsistent with our arguments which states the higher population density is the more environmental pollution would be.

The same as the case of carbon dioxide, the positive coefficient of trade also supports the pollution heaven hypothesis. The evidence indicates that trade liberalization has negative impacts on energy consumption, and an increase in the level of openness would lead to a rise in energy consumption. There is no evidence support the factor endowment hypothesis. The coefficients of GDP growth and FDI are insignificant and ambiguous in the regression for both pollutants of carbon dioxide and energy consumption. Some effects may work against each other.

Trade liberalization has resulted in increases in environmental pollution in these countries. Therefore, trade openness did not tend to improve environment due to the efficiency use of resources and the increasing competitiveness. The use of technological advances leading to an increase in efficiency, reduction in the cost of abatement or increases in awareness of pollution issues raise demand for environmental regulations. In the presence of environmental externalities and international trade, trade liberalization would harm environmental quality and sustainable development in these countries in East Asia.

7. Conclusions and policy implications

This paper provides a comprehensive picture of possible effects of trade liberalization and per capita income on the environment quality. The evidence indicates the monotonically increasing linear trend for the relation between per capita income and pollutants of both carbon dioxide and energy consumption. There is no evidence for the existence of an EKC for both environmental pollutants of carbon dioxide and energy consumption. No evidence supports the factor endowment hypothesis (FEH) that trade liberalization is good for the developing countries in East Asia. However, there is an evidence support the pollution heaven hypothesis that considers the link between trade and environment. Some criteria such as capital- labor endowment, endowment with natural resources or strictness of environment policies could help to have better insights.

The econometric model applied in the paper can be considered as a useful tool to examine linear, heteroscedasticity and autocorrelation data for other pollutants such as water, industrial waste, toxic gas, etc. The application of environmental policies should be paid attention to and consistent with specific characteristics and development stages at each country.

In the presence of environmental externalities, whether or not trade liberalization is good for developing countries. The evidence suggests that trade liberalization is harmful for the environment in developing and poor countries. This indicates that economic and environmental policies need to be coordinated to play a greater role for the reduction of negative effects of trade liberalization on the environment.

Some global pollution issues such as CO2 and global warming require international cooperation and need to be paid special attention to. The efforts of international cooperation on the environment may avoid a “free ride problem”. The awareness and pressure of the population could play an important role on the perceived benefits of environmental change and a strong driving force for policy makers.

In developing countries, solving environmental problems are not necessarily hurt economic growth (Grossman and Krueger 1995). However, developing countries always have ill institutional capacity for making sound and strict environmental protection policies. The more open economies to trade and foreign direct investment would increase the pollution levels as suggested by this study. The evidence also raises concerns for the “race to the bottom” in developing countries for the intensive competition of FDI attraction. Developed countries should help developing countries to build their capacity for making sound environmental policy, to assist techniques and finances, and to make environment friendly methods of production.

This study may have some limitations as such the incomplete and unreliable data availability, particularly for developing countries and the limited information gaining from the model because of the high level of aggregation. This model would be significant increasingly if it was broadened and included more other developing economies and explanatory variables. Some of the empirical results are consistent with the previous studies. However, they indicate no unique relationship between trade liberalization, per capita income and the environment for all countries and pollutants. It needs to have further in depth- studies on the trade liberalization’s impacts on the environment and income- environment relations.

Having an insightful analysis for the relationship between trade liberalization and the environment plays a crucial role and is helpful for environmental policy makers in developing countries. At higher levels of incomes, it seems to increase demand for strict environmental regulations and investment in abatement technologies. It is not clear whether developing countries follow a similar pollution- income path as some developed countries. However, there is no doubt that income elasticity of demand for pollution intensive products falls as incomes increase. For a late comer, Vietnam needs to build up and coordinate economic and environmental policies for the protection of environment and achieving sustainable development.

Table 1: Descriptive statistics

Variables	Mean	Std. Dev	Min	Max
Energy consumption	26.50535	23.60734	3.08748	100.6928
Carbon dioxide	1.778828	1.511246	0.23324	6.40294
Per capita GDP	1216.451	1028.053	186	4535
GDP growth rate	6.092407	4.124297	-13	15
Trade	83.16049	50.23773	19	228
Foreign Direct Investment (FDI)	0.0244874	0.0223661	-0.0032665	0.1193948
Population density	136.377	62.93917	41.74028	287.5457
Number of countries	6			
Number of years	27			
Number of observations	162			

Table 2: Estimation results for the fixed effect model for carbon dioxide

Variables	Coefficient	t- statistics
Intercept	-0.2110687^{***}	-1.75
Per capita GDP	0.0015687^{*}	29.80
GDP growth rate	-0.0081827^{***}	-1.90
Trade	0.0023365^{**}	2.13
Foreign Direct Investment (FDI)	0.1688006	0.19
Population density	-0.0004908	-0.42
$F(5,151)$[1]	548.32^{**}	
$F(5, 151)$[2]	284.49^{**}	
Hausman χ^2 (4) test	14.19^{**}	
Number of observations	162	

Estimation is made with a cross- country sample of 6 countries in East Asia for the period of 1980- 2006 by using the within regression. The dependent variable is the carbon dioxide. The first F test is for the significant of conjoint explanatory variables. The second F test is for the significant of heterogeneity. The Hausman test is for differentiating between the random effect model and the fixed effect model. Significant level: *1%, **5% and ***10%.

Table 3: Estimation results for the random effect model for energy consumption

Variables	Coefficient	z-statistics
Intercept	2.219393*	0.92
Per capita GDP	0.0194815*	13.28
GDP growth rate	0.4979969*	3.35
Trade	0.0185132	0.66
Foreign Direct Investment (FDI)	55.38848***	1.78
Population density	-.0391726	-3.00
Wald chi2(5)	1563.83*	
Number of observations	162	

Estimation is made with a cross- country sample of 6 countries in East Asia for the period of 1980- 2006 by using the Generalized Least Squares (GLS) regression. The dependent variable is the energy consumption. Significant level: *1% and ***10%

Table 4: Estimation results for carbon dioxide with the correction of heteroscedasticity and autocorrelation

Variables	Coefficient	z-statistics
Intercept	0.1836027	1.56
Per capita GDP	0.0012385*	18.77
GDP growth rate	-0.0002581	-0.11
Trade	0.0014568**	2.10
Foreign Direct Investment (FDI)	0.5181289	0.88
Population density	-0.0014681**	-2.18
Wald chi2(5)	551.37*	
Common AR(1) coefficient for all panels	0.8415	
Number of observations	162	

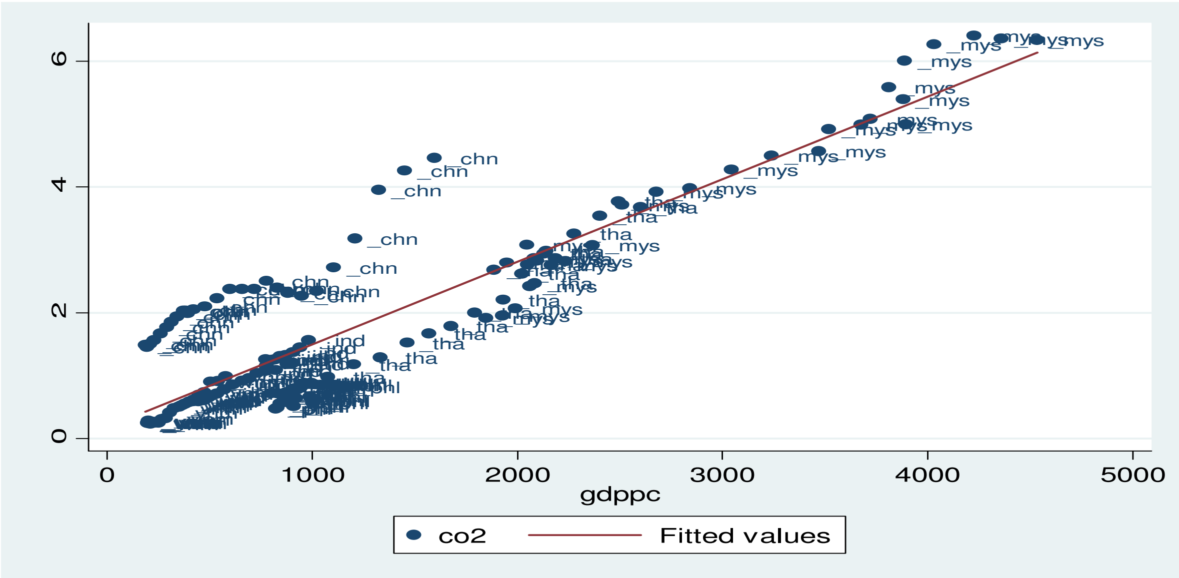
Estimation is made with a cross- country sample of 6 countries in East Asia for the period of 1980- 2006 by using the feasible generalized least squares (FGLS) regression and autocorrelation structure for correcting heteroscedasticity and autocorrelation. The dependent variable is the carbon dioxide. Significant level: *1% and **5%

Table 5: Estimation results for energy consumption with the correction of heteroscedasticity and autocorrelation

Variables	Coefficient	z-statistics
Intercept	0.9407799	0.61
Per capita GDP	0.0191888*	21.23
GDP growth rate	-0.0036318	-0.12
Trade	0.0261686*	3.19
Foreign Direct Investment (FDI)	5.897469	0.85
Population density	-0.0143953***	-1.67
Wald chi2(5)	678.56*	
Common AR(1) coefficient for all panels	0.8475	
Number of observations	162	

Estimation is made with a cross- country sample of 6 countries in East Asia for the period of 1980- 2006 by using the feasible generalized least squares (FGLS) regression and autocorrelation structure for the correction of heteroscedasticity and autocorrelation. The dependent variable is the carbon dioxide. Significant level: *1% and ***10%

Figure 1: The relationship between carbon dioxide and per capita GDP



(_chn: China; _ind: Indonesia; _mys: Malaysia; _phl: Philippines; _tha: Thailand; and _vnm: Vietnam)

Figure 2: The relationship between carbon dioxide and the level of openness

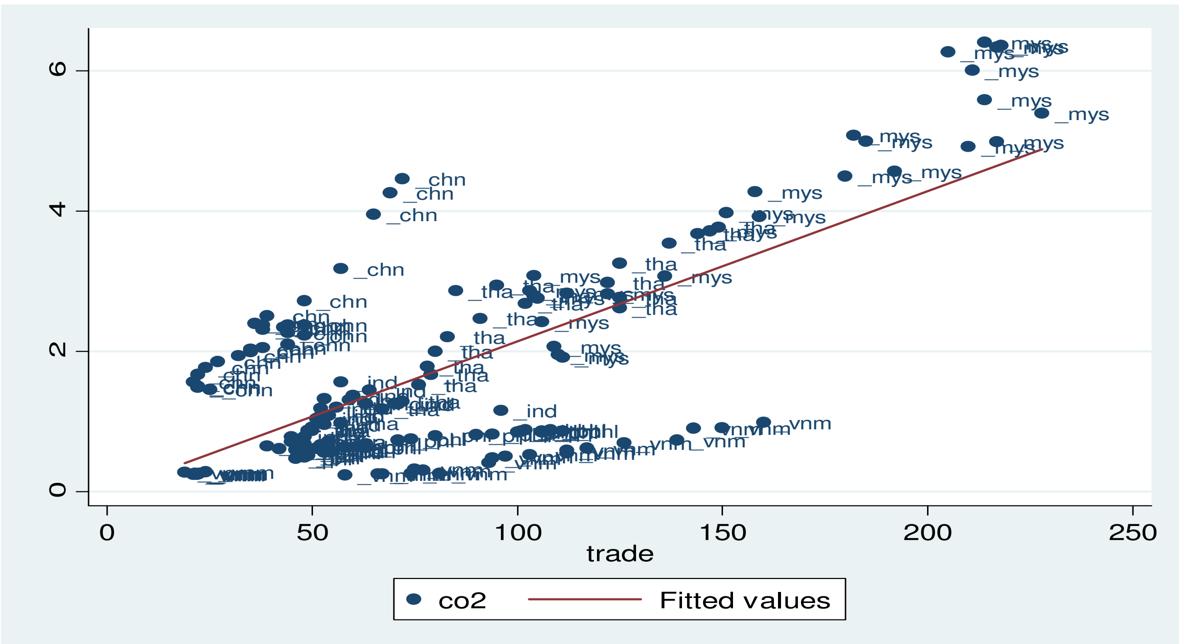


Figure 3: The relationship between carbon dioxide and foreign direct investment

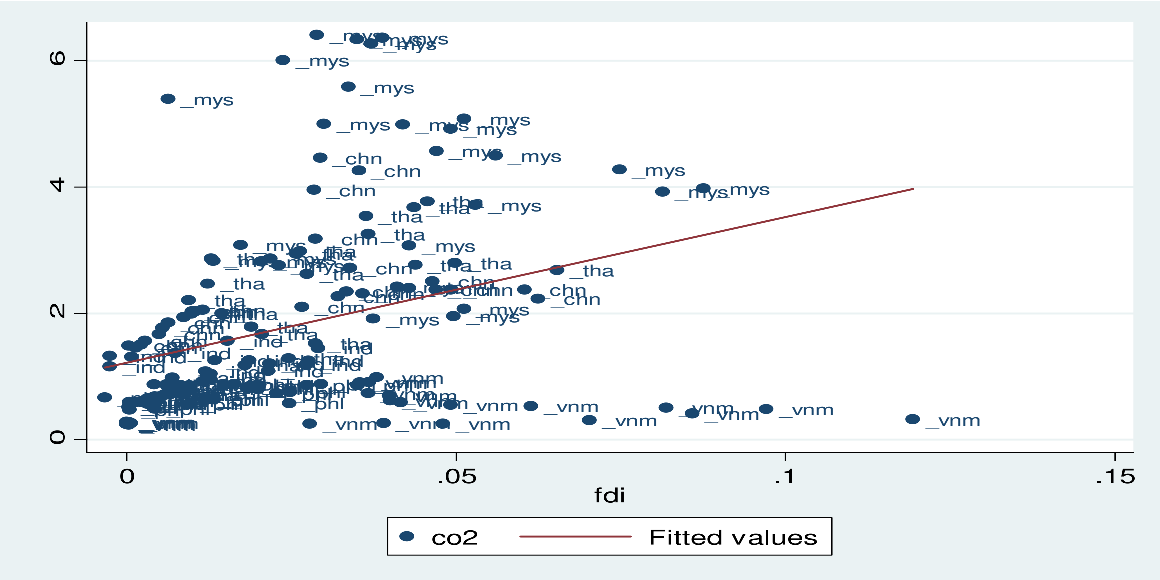


Figure 4: The relationship between energy consumption and per capita GDP

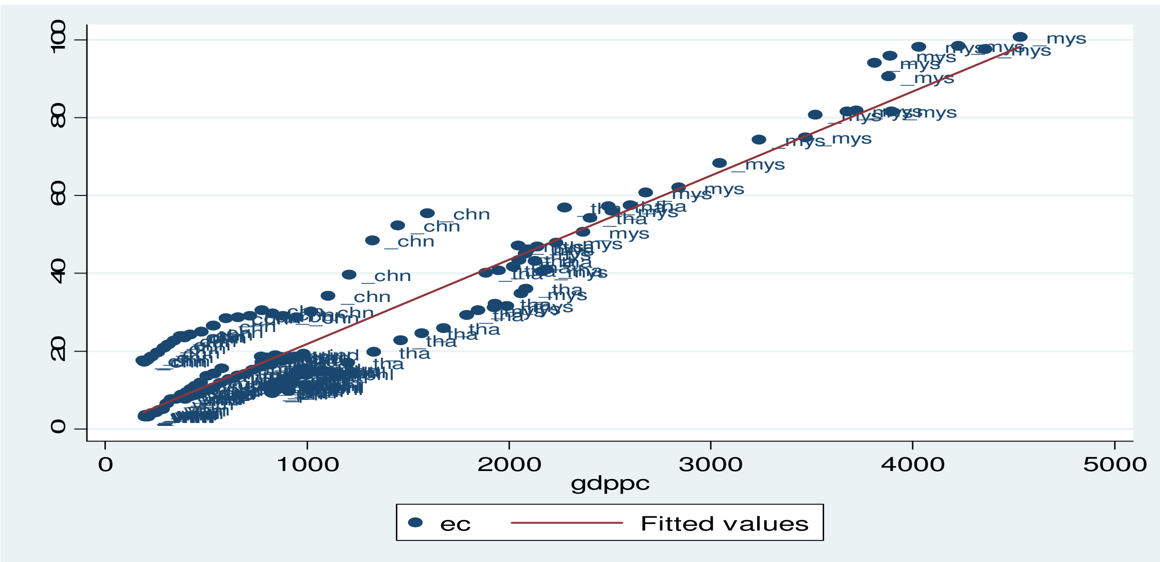


Figure 5: The relationship between energy consumption and the level of openness

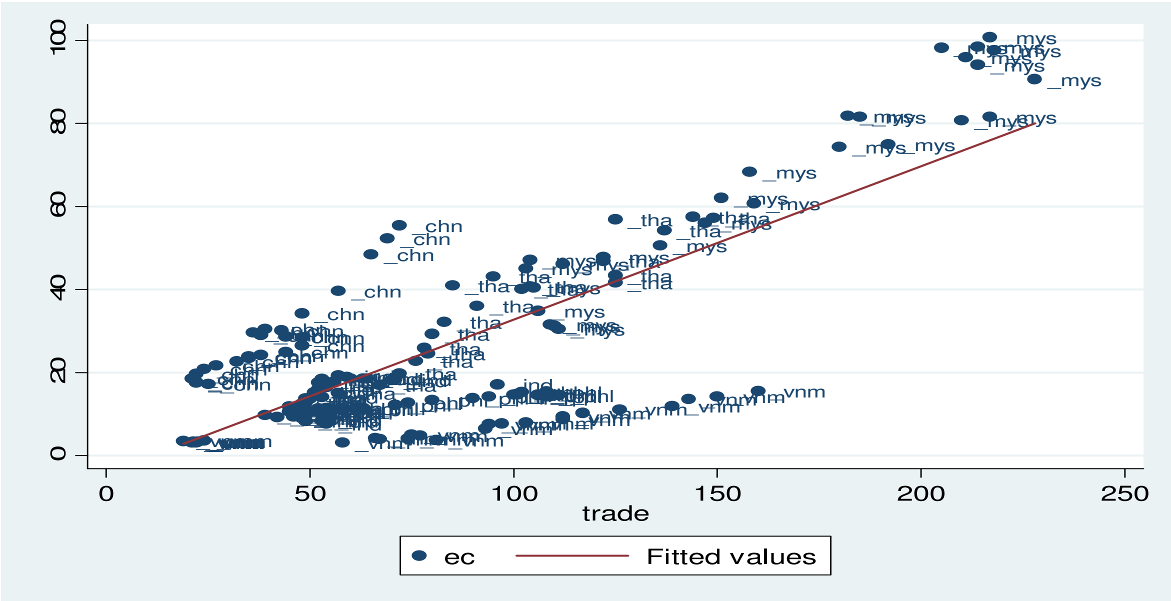
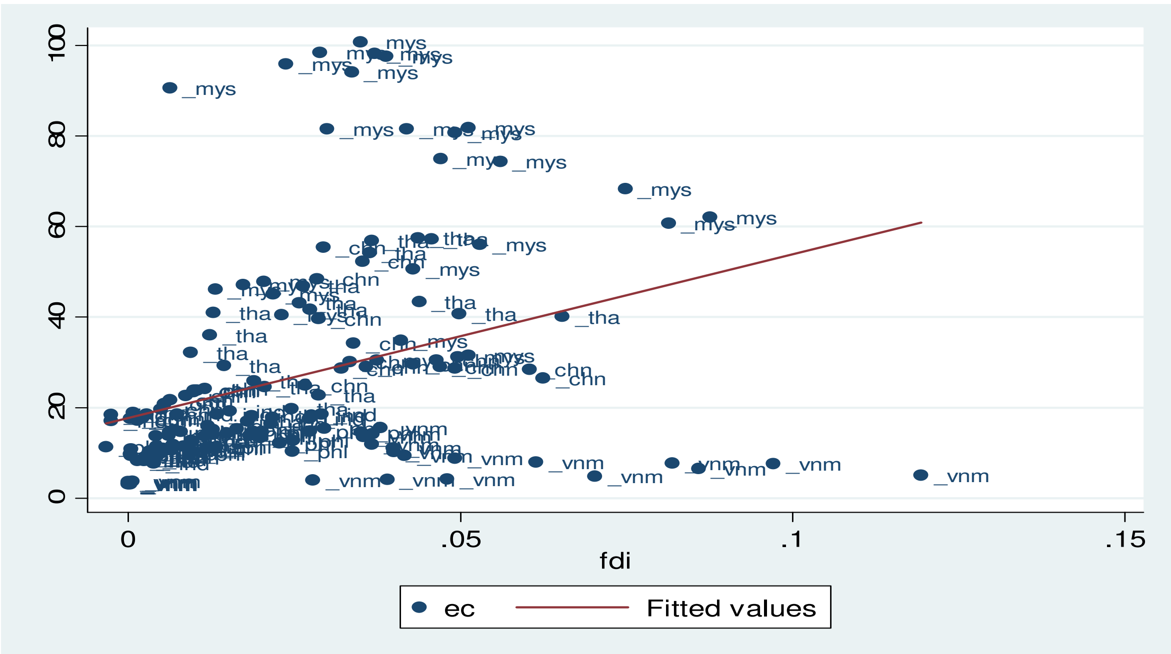


Figure 6: The relationship between energy consumption and foreign direct investment



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