The Effects of FDI, Economic Growth and Energy Consumption on Carbon Emissions in ASEAN-5: Evidence from Panel Quantile Regression

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Abstract: This study investigates the impact of foreign direct investment (FDI), economic growth and energy consumption on carbon emissions in five selected member countries in the Association of South East Asian Nations (ASEAN-5), including Indonesia, Malaysia, the Philippines, Singapore and Thailand. This paper employs a panel quantile regression model that takes unobserved individual heterogeneity and distributional heterogeneity into consideration. Moreover, to avoid an omitted variable bias, certain related control variables are included in our model. Our empirical results show that the effect of the independent variables on carbon emissions is heterogeneous across quantiles. Specifically, the effect of FDI on carbon emissions is negative, except at the 5th quantile, and becomes significant at higher quantiles. Energy consumption increases carbon emissions, with the strongest effects occurring at higher quantiles. Among the high-emissions countries, greater economic growth and population size appear to reduce emissions. The results of the study also support the validity of the halo effect hypothesis in higher-emissions countries. However, we find little evidence in support of an inverted U-shaped curve in the ASEAN-5 countries. In addition, a higher level of trade openness can mitigate the increase in carbon emissions, especially in low- and high-emissions nations. Finally, the results of the study also provide policymakers with important policy recommendations.

Keywords: Carbon emissions, Economic growth, FDI, Energy consumption, Panel quantile regression, ASEAN countries.

1. Introduction

In recent years, climate change and global warming have emerged as some of the most serious problems facing the international community. The human effect on the climate system is clear, and the recent anthropogenic emissions of greenhouse gases, especially carbon emissions, are the highest in history. Climate changes have had a widespread influence on human and natural systems[1]. Therefore, across the world, a considerable amount of attention has been paid to controlling carbon emissions and developing a low-carbon economy. The two most important variables related to environmental degradation are economic growth and energy consumption. Although they have become decisive factors in environmental pollution, the majority of studies limit their analyses only to environmental

[1] IPCC (Intergovernmental Panel on Climate Change), 2014, climate change 2014 synthesis Fifth Assessment Report.

pollution, particularly CO2 emissions, which correlate with energy consumption and economic growth. Energy consumption and economic growth alone may not explain CO2 emissions (Zhang, 2011; Ozturk et al, 2013). Therefore, we need to consider other variables that are associated with carbon emissions.

Although FDI has become increasingly important, few details have been discussed in this regard, especially in the ASEAN context. Indeed, the rising FDI flow in developing countries raises an important question regarding whether it has any environmental consequence (Zeng and Eastin 2012). Therefore, research on the effect of FDI on carbon emissions is necessary. Although ASEAN is active in attracting FDI, previous studies lack an analysis of the complexity correlation of FDI and CO2 emissions as well as the causality, which leads to poorer discernment in the pollution haven hypothesis. The conventional view may suggest that, with relaxed environmental standards in developing countries, FDI may promote CO2 emissions at large (Pao and Tsai, 2011). To attract foreign investment, developing countries have a tendency to ignore environmental concerns through relaxed or non-enforced regulation; in economic theory, this phenomenon is designated the pollution haven hypothesis. However, the effect of FDI can be inverted when low-carbon technologies are introduced to reduce the carbon dioxide emissions by FDI as a whole or when FDI flows to focus on the service industry. It is believed that foreign companies use better management practices and advanced technologies that are conducive to a clean environment in host countries (Zarsky, 1999), which is known as the halo effect hypothesis. Similarly, Zeng and Eastin (2012) find that overall FDI inflows in less-developing countries promote better environmental awareness.

In addition to these issues, existing studies also fail to find evidence of a consensus concerning the impact of economic growth on CO2 emissions. Although the Environmental Kuznet Curve (EKC) hypothesis postulates an inverted U-shaped relationship between economic growth and CO2 emissions, there is some evidence that the EKC hypothesis is a linear relationship (Khalid and Muhammad, 2013) and an N-shaped relationship (He and Richard, 2010), and some find that the EKC hypothesis is invalid. Several reasons may explain the considerable differences in conclusion: The samples used for analysis are different; the model and the method employed to estimate the relationship vary; and the control variables included in the model are diverse (Narayan and Smyth, 2009; Rafiq et al, 2009; Esteve and Tamarit, 2012). We argue that the main shortcoming of these studies is that the result may be biased due to neglect of distributional heterogeneity. In this paper, we examine the determinants of CO2 emissions considering distributional heterogeneity in panel quantile regression framework.

The impact of energy consumption on CO_2 emissions is also controversial. Some studies find that energy consumption has a positive effect on CO_2 emissions (Acaravci and Ozturk, 2010; Pao et al, 2011), whereas some studies show that CO_2 emissions are not attributable to energy consumption (Salim et al, 2008; Apergis et al, 2010; Menyah and Wolde-Rufael, 2010). One of the limitations of previous studies is that they involve only two or three variables and thus suffer from omitted-variable bias. Therefore, to avoid omitted-variable bias, we consider relevant variables as control variables. According to the previous literature, such as the studies by Shi (2003), Boutabba (2014), Rafiq et al. (2015) and You et al. (2015), we choose trade openness, population size, the industrial structure, and financial development as control variables.

The motivation behind using a panel quantile regression fixed effect model on emissions is threefold: First, we employ the panel data framework to research the determinants of CO_2 emissions in ASEAN countries because it has the advantage over focusing on a single country of providing more informative data, more variability, more degrees of freedom and thus greater efficiency in estimation (Lean and Smyth, 2010). Moreover, panel data model accommodates the special heterogeneity indicated by region-specific, non-observable and time-invariant intercepts. In addition, many of the environmental problems confronting ASEAN members have a trans-boundary character and thus demand a collective response. Therefore, it makes sense to examine the determinants of CO_2 emissions for ASEAN countries within the panel data framework. Second, this method can describe the entire conditional distribution of the dependent variable; therefore, it helps us obtain a more complete picture of the factors associated with pollutant emissions. Specifically, quantile regression estimators provide one solution to each quantile. Using this methodology, we can assess the determinants of emissions throughout the conditional distribution, especially in the countries with the most and least emissions. From a policy perspective, it is more interesting to know what occurs at the extremes of a distribution. By contrast, OLS regression techniques are not suitable for making environmental protection policies for high-emissions countries. Third, the panel quantile regression estimation results are robust to outlying observations of the explained variable and are more effective than OLS regression, especially when the error term is non-normal, which will help policymakers formulate more accurate environmental protection policies. However, only a few papers have applied a panel quantile regression fixed effect model to investigate the relationship among variables (Damette and Delacote, 2012; Flores et al., 2014; Yaduma et al., 2015).

Therefore, we use a panel quantile regression fixed effect model to explore the impact of FDI, economic growth and energy consumption on carbon emissions in five selected ASEAN countries. This paper makes three contributions: First, this study provides a more detailed description of the determinants of carbon emissions throughout the conditional distribution, especially in the highest and lowest quantiles. This approach provides a new perspective to understanding how the factors impact carbon emissions. Specifically, the analytical method of this study allows us to ascertain the validity of the pollution haven hypothesis, the halo effect hypothesis and the EKC hypothesis in five selected ASEAN countries. Second, certain related control variables are included in our model, which may resolve the omitted-variable bias problems that previous studies have faced. This issue has often been overlooked in previous studies, despite its importance (Lean and Smyth, 2010). Third, because of the method used, we find that economic growth and population have a negative effect on carbon emission among the high-emissions countries, in contrast with the previous findings. Therefore, the results of this study are also expected to provide useful information to policymakers in drafting effective environmental and economic growth policies.

The remainder of the paper is organized as follows. Section 2 is a brief introduction on the ASEAN context. Section 3 reviews the related literature. Section 4 introduces the methodology and data. Section 5 presents the empirical results and analysis. Finally, the conclusion and policy recommendations are presented in Section 6.

2. The ASEAN context

The selected ASEAN countries (ASEAN-5), i.e., Indonesia, Malaysia, the Philippines, Singapore, and Thailand, have developed well economically compared with other ASEAN members. These five countries were the original founding members of ASEAN in 1967, and they remain the most influential members of ASEAN in the 21st century. Among the ASEAN countries, in terms of per capita income in 2011, Singapore (USD 34,758) ranked the highest, followed by Malaysia (USD 6318), Thailand (USD 3163), Indonesia (USD 1570) and the Philippines (USD 1403). ASEAN's average annual economic growth rate remained above 5% from 2000 to 2013, which far exceeds the OECD average (1.6%) and is comparable to the growth experienced by India (7.2%) and Africa (4.8%)[2]. The continuous growth of the ASEAN-5 raises an interesting question among policymakers. Have the ASEAN-5 suffered the Kuznets effect and hence reached a certain income threshold to reverse the influence of economic growth on carbon dioxide emissions? Similarly, the increasing per capita income may also significantly contribute to environmental pollution. Therefore, given the impressive growth rate of these countries in the past, validating and testing this hypothesis is necessary.

Experts expect that growth in the ASEAN energy demand will be higher, with an average annual rate of 4% compared with the world average of 1.8%[3]. Indeed, there is evidence that higher fossil fuel use will become a challenge for policymakers, especially in terms of managing the issue of climate change. CO_2 emissions are expected to increase by 5.1% annually as a result of primary energy consumption. According to the latest statistics, ASEAN's share of global emissions, which was 4% in 2013, is small, but it will nearly double by 2040. CO_2 emissions grow at a faster pace than the primary energy demand because of the increasing share of coal in the energy mix[4]. The goal of the ASEAN Vision 2020 is to pursue a consistent approach to regional cooperation in pooling and maximizing the efficient utilization of resources. Indeed, ASEAN's position in playing an important role in reducing the emissions footprint proves the importance of understanding the sources of emissions and their determinants.

The impact of FDI on carbon emissions has received considerable attention in developing countries

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[2] World Energy Outlook Special Report 2015: Southeast Asia Energy Outlook 2015.
[3] IEA. World Energy Outlook 2009. Paris: International Energy Agency.
[4] World Energy Outlook Special Report 2015: Southeast Asia Energy Outlook 2015.

(He, 2006; Kearsley, 2010), but apart from a few studies, little is currently known with respect to ASEAN (Elliott and Shimamoto, 2008; Atici, 2012). By attracting a significant amount of FDI inflows to increase investment, ASEAN countries take FDI-led growth strategies to propel their economic growth. Significantly, the liberalization efforts of each individual country have been long-lasting, and as a whole, ASEAN has become one of the leading regions among developing countries in attracting FDI. In particular, in the past, the ASEAN-5 made great efforts to attract large amounts of FDI, with Singapore leading the alliance. The latest statistics show that ASEAN saw the strongest increase in FDI inflows in 2014, with levels exceeding the inflows to China for the first time since 1993, making ASEAN the largest recipient of FDI in the developing world[5]. Although the benefits of export-oriented strategies are multifaceted, they come at a cost, particularly to the environment. In addition, FDI inflows that significantly cultivate industrialization have increased concerns regarding sustainable development in ASEAN countries (Karki et al., 2005). Given the significant amount of capital inflows in ASEAN-5, it is essential to verify the effects of these capital inflows on environmental pollution.

3. Literature review

The literature review shows that the relationships among CO_2 emissions, FDI, economic growth and energy consumption can be broadly classified into three research clusters. First, the empirical work focusing on the relationship between CO_2 emissions and economic growth tests the validity of the ECK hypothesis. Second, analyses focus on the energy-CO_2 emissions nexus, and third, analyses focus on the FDI-pollution nexus to verify the validity of the pollution haven hypothesis. Nevertheless, for ASEAN countries, a limited number of studies are available.

Following the seminal work of Grossman and Krueger (1995), numerous studies have investigated the relationship between economic growth and environmental pollution under the heading of the environmental Kuznets curve (EKC) hypothesis; these studies include those by Suri and Chapman (1998), Dinda and Coondoo (2006), Managi and Jena (2008), and Zhu et al. (2012). Nevertheless, recent studies appear to present mixed empirical results on the validity of the EKC. For example, Lean and Smyth (2010) conduct a study utilizing a panel vector error correction model analysis of the EKC to find the relationship between economic growth and CO_2 emissions in five ASEAN countries. Using annual data from the period 1980-2006, the empirical results suggest that, overall, there seems to be evidence supporting the EKC hypothesis in the ASEAN-5. However, by comparing the long-run and short-run income elasticity, Narayan and Narayan (2010) argue that in none of the countries (Indonesia, Malaysia, the Philippines and Thailand) is the EKC hypothesis supported. Similarly, Chandran and Tang (2013) employ the cointegration and Granger causality methods to test the EKC hypothesis for the ASEAN-5 countries based on annual data from 1971 to 2008. They find that the inverted U-shaped

[5] ASEAN Investment Report 2015 Infrastructure Investment and Connectivity.

EKC hypothesis is not applicable to the ASEAN-5 economies. Furthermore, Heidari et al. (2015) test the relationships among economic growth, energy consumption and carbon emissions by using a panel smooth transition regression model. The empirical results also support the validity of the EKC hypothesis in the ASEAN countries.

With regard to the energy consumption-CO_2 nexus, Lean and Smyth (2010) find a significant long-run association between electricity consumption and emissions in all of the ASEAN-5 countries. The Granger causality panel indicates that unidirectional Granger causality runs from emissions to electricity consumption only in the short run. However, Bloch et al. (2012) investigate the relationship between coal consumption and emissions in China using both supply-side and demand-side frameworks, and their results reveal that there is bi-directional causality between coal consumption and pollutant emission both in the short and long run. Saboori and Sulaiman (2013) also find a bi-directional Granger causality between energy consumption and CO_2 emissions in all five ASEAN countries. The implication is that carbon emissions and energy consumption are highly interrelated. Furthermore, Tang and Tan (2015) use the cointegration and Granger causality methods to examine the impact of energy consumption, income and FDI on carbon emissions in Vietnam. They find that energy consumption is a Granger-cause of CO_2 emissions in the short run and the long run. Moreover, the study concludes that energy consumption, FDI and income are the key determinants of CO_2 emissions in Vietnam. Similarly, Wang et al. (2016) investigate the nexus between urbanization, energy use, and carbon emissions in a panel of ASEAN countries by using the panel fully modified ordinary least squares technique. The empirical results indicate a statistically significant positive relationship between energy use and carbon emissions in the long run.

In terms of the FDI-pollution nexus, there are two conflicting hypotheses in previous studies: the pollution haven hypothesis and the halo effect hypothesis. Cole (2004) examines the extent to which the EKC inverted U relationship can be explained by trade and, specifically, the migration or displacement of 'dirty' industries from the developed regions to the developing regions (the pollution haven hypothesis). Using detailed data on North–South trade flows for pollution-intensive products, the evidence for the pollution haven hypothesis is assessed. The results show that there is evidence of pollution haven effects. Asghari (2013) tests the validity of the pollution haven and halo pollution hypotheses in the context of FDI by determining the correlations between carbon emissions and FDI inflow over the period 1980-2011 in selected MENA countries. The statistical results from correlation analysis show that FDI inflow has a weak and statistically significant negative relationship with CO_2 emission which suggests weak support for the halo pollution hypothesis. However, the literature examining the impact of FDI on the host country's environment is very scarce in the case of ASEAN countries. Merican et al. (2007) assess the relationship between FDI and pollution in the ASEAN-5. Employing autoregressive distributive lag estimation, they find that FDI increases emissions in Malaysia, Thailand, and the Philippines; however, there appears to be an inverse relationship between

FDI and pollution in Indonesia. Atici (2012) examines the interaction between trade and the environment in terms of carbon emissions for the group of ASEAN countries. Using both a random effects and a fixed effects panel analysis, the panel results show that FDI has a negative effect on CO_2 emissions, which indicates that FDI benefits the ASEAN countries in reducing pollution overall. However, the results for the group of countries including Indonesia, Malaysia, Thailand and the Philippines indicate that FDI does not have any significant effect on CO_2 emissions.

It is clear that there are some inconclusive and mixed results concerning the relationships among CO_2 emissions, FDI, economic growth and energy consumption. Indeed, the evidence for the pollution haven hypothesis and the halo effect hypothesis is limited. The majority of studies have been conducted on single countries and involve only two or three variables, suffering from omitted-variable bias. However, a few studies have employed a panel quantile regression fixed effect model to examine the relationships among the variables. Damette and Delacote (2012) investigate the deforestation factors at a global level by using a quantile approach. Flores et al. (2014) apply methods for conditional quantile panel fixed effects models to estimate the income-emissions relationship, using U.S. state-level data on NO_x and SO_2 pollutants over the period 1929-1994. The empirical results show that the relationship between income and the environment is sensitive to the presence of outliers in the data. Yaduma et al. (2015) employ a quantile fixed effects technique in exploring the CO_2 environmental Kuznets curve within two groups of economic development (OECD and non-OECD countries) and six geographical regions.

4. Methodology and data

4.1 Fixed effect panel quantile regression

In this paper, we use a fixed effect panel quantile regression model to investigate the impact of FDI, economic growth and energy consumption on carbon emissions. By using a panel quantile regression methodology, we can examine the determinants of carbon emissions throughout the conditional distribution, especially in the countries with the most and least emissions. However, traditional regression techniques focus on the mean effects, which may lead to under- or over-estimating the relevant coefficient or even failing to detect important relationships (Binder and Coad, 2011).

The quantile regression technique was introduced in the seminal paper by Koenker and Bassett (1978). This method is a generalization of median regression analysis to other quantiles. The conditional quantile of y_i given x_i is as follows:

$$Q_{y_i}(\tau \mid x_i) = x_i^T \beta_\tau \,. \tag{1}$$

Quantile regression is robust to outliers and heavy distributions. However, these methods do not take into account the unobserved heterogeneity of a country. In this paper, we employ a panel quantile method with fixed effects, which makes it possible to estimate the conditional heterogeneous covariance effects of carbon emissions drivers, thus controlling for unobserved individual heterogeneity. Some works, such as those by Koenker (2004), Lamarche (2010), Galvao (2011) and Canay (2011), are focused on the econometric theory of applying quantile regressions to panel data. Consider the following fixed effect panel quantile regression model:

$$Q_{y_{it}}(\tau_k \mid \alpha_i, x_{it}) = \alpha_i + x_{it}'\beta(\tau_k), \tag{2}$$

The major problem with fixed effect panel quantile regression is that the inclusion of a considerable amount of fixed effects (α_i) is subject to the incidental parameters problem (Lancaster, 2000; Neyman and Scott, 1948). The estimator will be inconsistent when the number of individuals goes to infinity but the number of observations for each cross-sectional unit is fixed. The main reason why the literature on fixed effect panel quantile regression is relatively scarce is that the inferior approaches to eliminating unobserved fixed effects are unfeasible in the quantile regression model. These methods rely on the fact that expectations are linear operators, which is not the case for conditional quantiles (Canay, 2011).

Koenker (2004) proposes an appropriate method for addressing such problems. The author treats unobservable fixed effect as parameters to be jointly estimated with the covariate effects for different quantiles. The unique characteristic of this method is the introduction of a penalty term in the minimization to address the computational problem of estimating a mass of parameters specifically; the parameter estimate is calculated as follows:

$$\min_{(\alpha,\beta)} \sum_{k=1}^{K} \sum_{t=1}^{T} \sum_{i=1}^{N} w_k \rho_{\tau_k} (y_{it} - \alpha_i - x_{it}^T \beta(\tau_k)) + \lambda \sum_{i}^{N} |\alpha_i|, \tag{3}$$

where i is the index for countries (N), T is the index for the number of observations per countries, K is the index for quantiles, x is the matrix of explanatory variables, ρ_{τ_k} is the quantile loss function. In addition, w_k is the relative weight given to the k-th quantile, which controls for the contribution of the k-th quantile on the estimation of the fixed effect. In this paper, we employ equally weighted quantiles $w_k = 1/K$ (Alexander et al, 2011; Lamarche, 2011). λ is the tuning parameter that reduces the individual effects to zero to improve the performance of the estimate of β. If the λ term goes to zero, then the penalty term disappears, and we obtain the usual fixed effects estimator. However, if the λ term goes to infinity, then we obtain an estimate of the model without individual effects. In this paper, we set $\lambda = 1$ (Damette and Delacote, 2012).

Furthermore, we study the effect of FDI, economic growth and energy consumption on carbon emissions by modifying the specifications of previous studies. We specify the conditional quantiles function for quantile τ as follows

$$\begin{aligned} Q_{y_{it}}(\tau \mid \alpha_i, \xi_t, x_{it}) = {} & \alpha_i + \xi_t + \beta_{1\tau} ENC_{it} + \beta_{2\tau} GDP_{it} + \beta_{3\tau} GDP_{it}^2 + \beta_{4\tau} POP_{it} + \beta_{5\tau} TRADE_{it} \\ & + \beta_{6\tau} INDUS_{it} + \beta_{7\tau} FDI_{it} + \beta_{8\tau} FINAN_{it} \end{aligned} \tag{4}$$

where the countries are indexed by i and time by time t. y_{it} is the emissions indicator. The descriptions of other variables are provided in the next section.

4.2 Variable, data description and descriptive statistic

The purpose of this paper is to investigate the impact of FDI, economic growth and energy consumption on carbon emissions by using data from five ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore and Thailand) over the period 1981-2011. The sample of ASEAN countries slightly shrinks when a related variable is considered as an independent variable, given that time series data for the entire period are unavailable or not fully available for other ASEAN counties.

Carbon emissions are a dependent variable and measured in terms of metric tons per capita. As previously indicated, carbon emissions are considered the primary greenhouse gas responsible for global warming. Our main variables of interest are FDI, economic growth, and energy consumption. FDI is the net inflow as a share of GDP. The real GDP per capita, an independent variable, is expressed in constant USD at 2005 prices, and energy consumption, also an independent variable, is expressed in terms of kg of oil equivalents per capita.

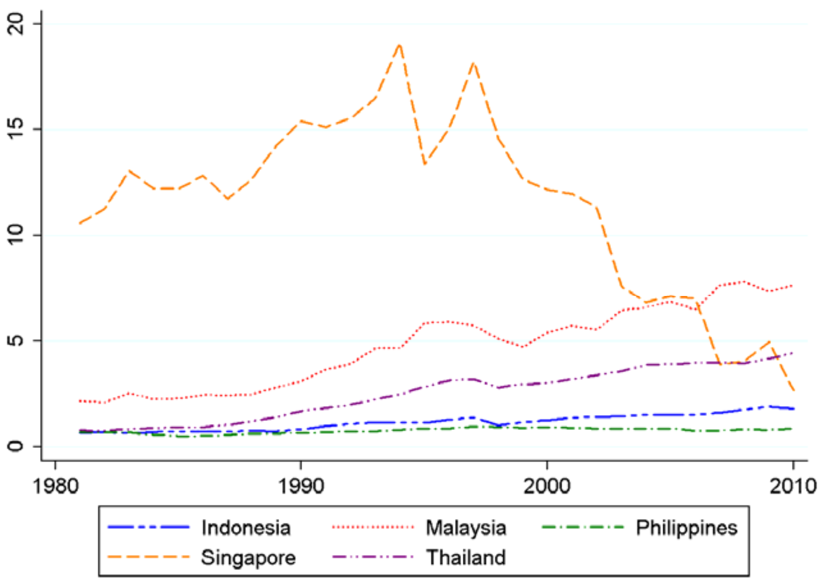

Fig. 1. CO_2 emissions (measured in metric tons per capita)

Fig. 1 depicts the time series of carbon emissions for five ASEAN countries. The carbon emissions in Singapore initially increase and then decrease; in particular, there has been a persistent decrease since 1997. However, a persistent increase in the emissions level can be observed in the other four countries. This finding is not surprising because Singapore is a developed country, which supports the EKC hypothesis, i.e., an inverted U-shaped relationship between environmental pollution and income. However, the other four countries are developing countries; thus, the trends for carbon emissions, economic growth and energy consumption are similar (see Fig. 3 and Fig. 4). This finding indicates that the factors that have prompted the persistent increase in carbon emissions are somehow related to the increase in economic activity and energy consumption.

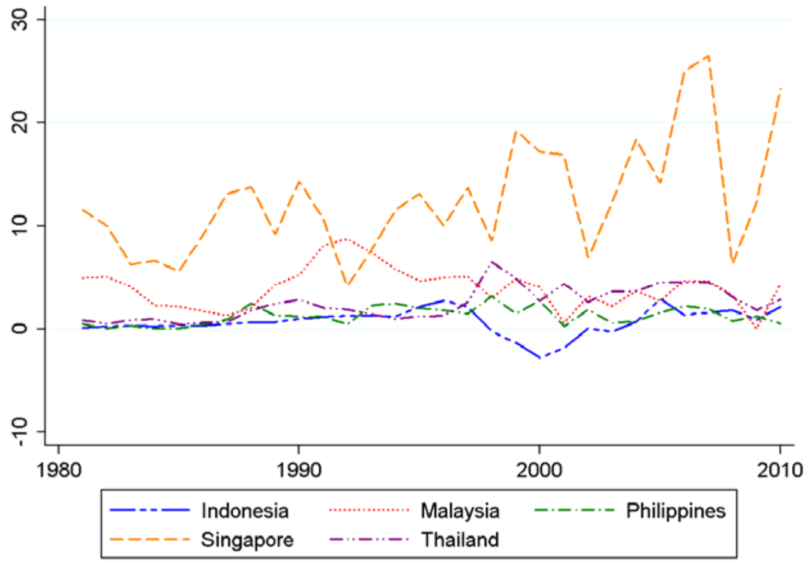

Fig. 2. FDI (measured as the share of net inflows in GDP)

Fig. 2 shows the time series of FDI for five ASEAN countries. The overall change in the series is much larger for the FDI series than it is for the other series. In particular, the FDI in Singapore has been increasing faster than in the other four countries over recent decades.

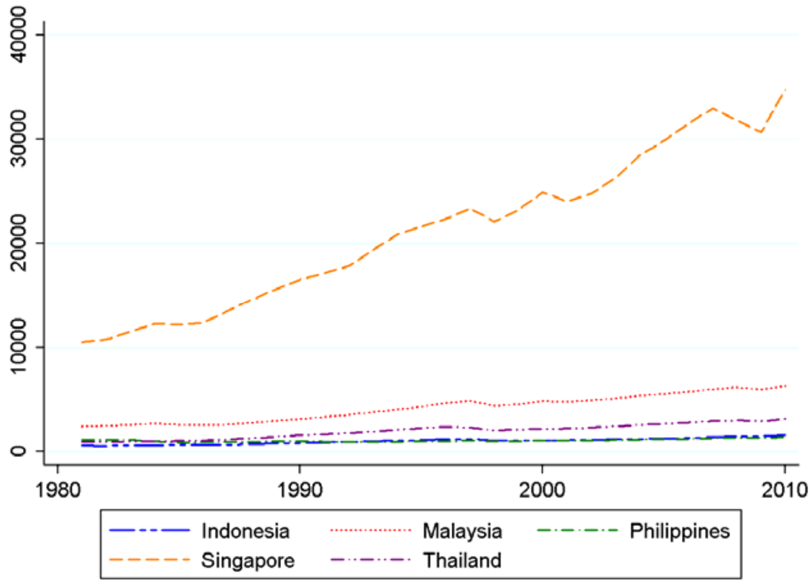

Fig. 3. GDP per capita (in constant 2005 USD)

Fig. 3 shows the time series of GDP per capita for five ASEAN countries. Overall, a persistent increase in the GDP per capita level can be observed in five ASEAN countries. In particular, the GDP per capita in Singapore is the highest by a large margin. There are some factors that may cause the difference in the level of economic development between Singapore and the other four countries, such as differences in natural resources, scientific and technological levels and the quality of the related policies. Indeed, compared with the other countries in the sample, Singapore shows the highest variation in terms of not only GDP per capita, but also carbon emissions and energy consumption.

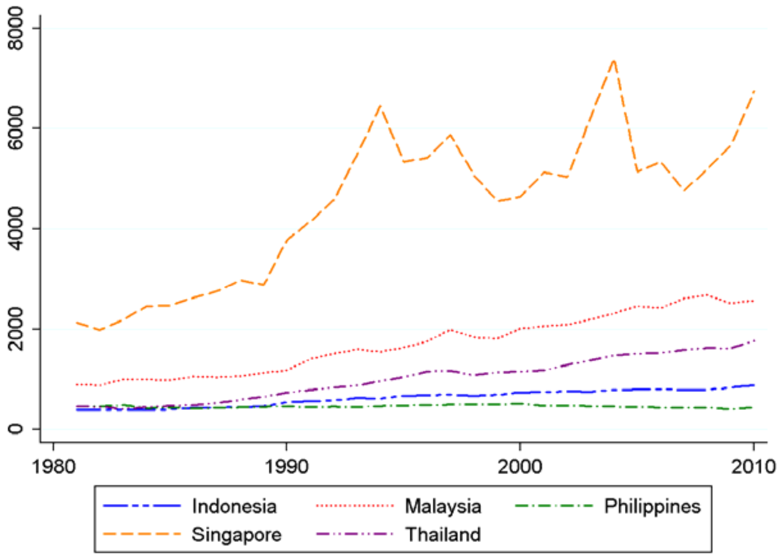

Fig. 4. Energy consumption (measured in kg of oil equivalents)

Fig. 4 shows the time series of energy consumption for five ASEAN countries. Once again, Singapore shows unique features with regard to energy consumption. Since 1994, the level of energy consumption in Singapore has been declining, but the economic development level has continued to increase (see Fig. 3). The reasons may be related to improved energy usage efficiency. However, the energy consumption in the other four countries in the sample is steadily growing.

Table 1. Variable definitions

Variable	Definition	Source
CO_2	Carbon dioxide emissions (metric tons per capita)	World Development Indicators
ENC	Energy consumption (kg of oil equivalents per capita)	World Development Indicators
GDP	Economic growth (real GDP per capita constant USD at 2005 prices)	World Development Indicators
POP	Total population	World Development Indicators
TRADE	Trade openness (% of GDP)	World Development Indicators
INDUS	The industrial structure (the share of the tertiary industry sector in GDP)	World Development Indicators
FDI	Foreign direct investment, net inflows (% of GDP)	World Development Indicators
FINAN	Financial development, domestic credit to the private sector (% of GDP)	World Development Indicators

Notes: All of the data are annual over the period 1981-2011.

Because the relationships among carbon emissions, economic growth, and energy consumption can be affected by others factors, it is appropriate to adopt a multivariate approach to avoid omitted-variable bias. According to the previous literature, a vector of additional explanatory variables consisting of trade openness, population size, the industrial structure and financial development is included in the model. Trade openness is measured by the share of trade openness in GDP. The population size is the total population of the country. The industrial structure is measured by the share of the industry value added to GDP. Financial development is the total value of domestic credit to the private sector as a share of GDP. Our data are collected from the World Development Indicators of the World Bank, and except for foreign direct investment, all variables are transformed into natural logarithms prior to empirical analysis. Details about the data are provided in Table1.

Table 2. Summary statistics

Variable	CO2	ENC	GDP	POP	TRADE	INDUS	FDI	FINAN
Mean	0.884	7.018	7.916	17.38	4.736	3.632	4.210	4.065
Std. Dev.	1.038	0.855	1.158	1.371	0.716	0.1371	5.201	0.675
Skewness	0.345	0.578	0.814	-0.581	0.397	-0.037	2.031	-0.524
Kurtosis	1.847	2.148	2.424	2.229	1.866	2.051	7.365	2.076
Minimum	-0.661	5.973	6.364	14.74	3.688	3.307	-2.757	2.367
Q1(.25)	-0.12	6.18	6.97	16.67	4.07	3.52	0.93	3.48
Median	0.814	6.837	7.657	17.84	4.630	3.646	2.260	4.311
Q3(.75)	1.74	7.64	8.53	18.22	5.29	3.74	5.02	4.61
Maximum	2.950	8.909	10.45	19.29	6.085	3.882	26.52	5.110
Jarque-Bera	11.27***	12.90***	18.65***	12.16***	11.98***	5.657**	222.2***	12.21***

Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 2 presents an overview of the descriptive statistics. Clearly, the distributions of all of the variables are skewed, and the kurtosis values show that the eight series distributions are more concentrated than the normal distribution with longer tails. The Jarque-Bera statistical test strongly rejects the null hypothesis of normality, indicating the non-normality of the unconditional distribution of all of the variables.

5. Empirical results and analysis

5.1 Panel unit root test and panel cointegration results

Before estimating the panel quantile regression models, we test whether the variables used are stationary. We conduct five panel unit root tests: the LLC test, the Breitung test, the IPS test, the Fisher-ADF test, and the Fisher-PP test. Moreover, we account for cross-sectional dependence as reported by Pesaran (2007)[6]. Table 3 presents the results of the panel unit root tests. These results indicate that the null hypothesis of the existence of a unit root could not be rejected for all of the variables at the selected level. However, the unit root null hypothesis for all of the variables at the first difference could almost be completely rejected at the 1% level. Therefore, an empirical analysis that uses the first difference sequence is necessary.

[6] Pesaran's test of cross-sectional independence = 43.421, P = 0.0000 and = 24.916, P = 0.0001 at levels and first difference, respectively. P-value indicates the rejection of null hypothesis of no cross-sectional independence.

Table 3. Panel unit root tests

Variable	CO2	ENC	GDP	POP	TRADE	INDUS	FDI	FINAN
Levels								
LLC	0.978	1.323	-1.369	-1.103	2.221	0.112	-2.546***	-0.529
Breitung	2.995	-1.104	0.235	5.158	1.487	-0.091	-2.717	-0.754
IPS	2.105	1.457	0.051	-0.118	1.439	0.774	-3.085	0.326
Fisher-ADF	5.081	3.152	8.059	12.25	9.246	6.058	28.13	6.111
Fisher-PP	5.696	3.575	5.102	48.52	10.41	8.773	49.62***	5.189
CSD-ADF	-0.893	-2.290	-2.240	-3.493***	-1.224	-1.717	-2.136	-2.224
First difference								
LLC	-8.727***	-6.374***	-6.153***	-1.143***	-8.159***	-10.97***	-9.229***	-4.816***
Breitung	-4.402***	-6.455***	-2.051***	-0.422	-4.032***	-4.846***	-2.960***	-6.804***
IPS	-9.314***	-6.892***	-6.627***	-3.322***	-8.781***	-10.57***	-10.55***	-5.515***
Fisher-ADF	84.10***	57.17***	54.99***	27.74***	74.14***	89.56***	103.5***	45.28***
Fisher-PP	189.9***	82.55***	35.85***	12.09	75.97***	355.5***	577.1***	45.08***
CSD-ADF	-3.937***	-4.579***	-2.997***	-2.529***	-3.640***	-3.435***	-3.741***	-3.375***

Note: 1) LLC, Breitung and IPS represent the panel unit root tests of Levin et al. (2002), Breitung (2000) and Im et al. (2003), respectively. Fisher-ADF and Fisher-PP represent the Maddala and Wu (1999) Fisher-ADF and Fisher-PP panel unit root tests, respectively. CSD-ADF represents the Pesaran's test of cross-sectional independence ADF. The maximum number of lags is set to three. The Schwarz information criterion (SIC) is used to select the lag length. The bandwidth is selected using the Newey-West method. Bartlett is used as the spectral estimation method. The exogenous variables are the individual effects and individual linear trends. 2) ***Statistical significance at the 1% level.

As the results of the panel unit root tests indicate that the variables contains a panel unit root, we can proceed to examine whether there is a long-run relationship among these variables using the Johansen Fisher panel cointegration test proposed by Maddala and Wu (1999). In the Johansen-type panel cointegration test, results are known to depend heavily on the VAR system lag order. Table 4 presents the results, which use one lag and indicate that seven cointegrating vectors exist.

Table 4. Johansen Fisher panel cointegration test

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	556.5	0.0000	213.6	0.0000
At most 1	393.2	0.0000	187.2	0.0000
At most 2	301.4	0.0000	135.4	0.0000
At most 3	166.0	0.0000	59.19	0.0000
At most 4	115.9	0.0000	49.61	0.0000
At most 5	74.29	0.0000	45.16	0.0000
At most 6	38.03	0.0000	21.56	0.0175
At most 7	27.49	0.0022	27.49	0.0022

* Probabilities are computed using an asymptotic Chi-square distribution.

5.2 Panel quantile regression results

To facilitate comparisons, the model is first estimated by pooled and fixed effects OLS regression estimates. Columns 1 and 2 in Table 5 present the pooled and one-way individual fixed effects OLS regression estimates, respectively. The FMOLS technique reported by Pedroni (2000) was employed to estimate long-run elasticities. Pedroni (2000) notes that common time dummies are intended to capture certain types of cross-sectional dependency. Column 4 reports the results of FMOLS. As noted by Baltagi (2008), time-period fixed effects control for all time specific, spatial-invariant variables whose omission could bias the estimates in a typical time series study. Thus, we are more concerned with the results of the model with a two-way fixed effect. Column 3 reports the results of two-way fixed effects. Only the effect of ΔTRADE is consistent in the different specifications.

Table 5. OLS regression results

Variable	OLS pooled	OLS one-way fixed effect	OLS two-way fixed effect	FMOLS
ΔENC	0.4056^{***} (2.9641)	0.4238^{***}(3.2362)	0.3279^{**}(2.1942)	0.5787^{***}(6.5156)
ΔGDP	0.3046(1.1721)	0.4704^{**}(1.8548)	0.0261(0.0610)	0.3145(1.3295)
ΔPOP	0.3957(0.3742)	2.2693^{*}(1.8563)	0.9312(0.6547)	0.5189(0.4644)
ΔTRADE	-0.2443^{**}(-2.3619)	-0.2464^{**}(-2.4948)	-0.3049^{**}(-2.2965)	-0.0908(-0.8259)
ΔINDUS	0.7498^{**}(2.3996)	0.5157^{*}(1.7092)	0.5429(1.4885)	0.2026(0.9539)
ΔFDI	-0.0105^{***}(-3.3798)	-0.0092^{***}(-3.0746)	-0.0078^{**}(-2.3118)	-0.0058^{**}(-2.0575)
ΔFINAN	0.0723(1.0316)	0.0355(0.5279)	-0.0016(-0.0201)	-0.1319(-1.0446)
Constant	0.0084(0.3467)	0.0501^{*}(1.8602)	0.0058(0.1699)	0.0000

Note: 1) ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. 2) Figures in parentheses are t-values.

To control for the distributional heterogeneity, the quantile regression with fixed effects in Koenker (2004) is used. As noted above, the omission of time-period fixed effects could bias the estimates in a typical time series study, which is the source of power for our focus on quantile regression analysis with a two-way fixed effect. Table 6 presents the results of the panel quantile regression estimation. The results are reported for the 5th, 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, 90th and 95th percentiles of the conditional emissions distribution. Overall, the empirical results indicate that the impacts of various factors on carbon emissions are clearly heterogeneous.

Table 6. Panel quantile regression results

Variable	Quantiles										
	5th	10th	20th	30th	40th	50th	60th	70th	80th	90th	95th
Constant	-0.0674***	-0.0335	-0.0044	0.0228	0.0448***	0.0273**	0.0293**	0.0441***	0.0452**	0.0513	0.1039
	(-2.6957)	(-1.6184)	(-0.2654)	(1.4905)	(3.1354)	(2.0828)	(2.1885)	(2.7376)	(2.1905)	(1.0345)	(1.3035)
ΔENC	0.0464	0.3531*	0.2334	0.3786**	0.4915**	0.5719**	0.5869***	0.5637***	0.5774***	0.7231***	0.1929
	(0.3442)	(1.7557)	(1.0540)	(1.3537)	(2.0096)	(2.4159)	(2.7688)	(3.5065)	(3.3981)	(4.1656)	(0.8797)
ΔGDP	0.7145***	0.9313***	1.1047***	0.8622***	0.7414***	0.6613***	0.5382***	0.6352***	0.4113	0.1271	-1.0378*
	(2.7702)	(4.5079)	(5.5013)	(3.8467)	(3.9149)	(3.9823)	(3.1773)	(3.3689)	(1.4731)	(0.2685)	(-1.7677)
ΔGDP^2	0.5737	0.9531	0.8017	1.5261	1.4821	3.7727	2.3067	7.8377	11.2679	18.5541*	28.0278***
	(0.2769)	(0.4613)	(0.3382)	(0.6862)	(0.6064)	(1.1188)	(0.6085)	(1.4098)	(1.3025)	(1.8050)	(3.4185)
ΔPOP	3.4545***	2.3899***	2.9035***	3.2845***	3.1755***	1.0914	0.7952	0.7194	0.2562	-1.9773*	-2.3416*
	(3.2012)	(2.7062)	(4.4676)	(4.7587)	(3.7526)	(1.3824)	(1.1088)	(1.0810)	(0.3218)	(-1.7170)	(-1.7496)
ΔTRADE	-0.4822***	-0.3767***	-0.2705*	-0.2273*	-0.1251	-0.0829	-0.1052	-0.0814	-0.0996	-0.3673**	-0.6623**
	(-3.4313)	(-2.8281)	(-1.8977)	(-1.9802)	(-1.0527)	(-0.7214)	(-1.0023)	(-0.6707)	(-0.6774)	(-1.8938)	(-2.5140)
ΔINDUS	0.1253	-0.0778	-0.1283	0.3264	0.2020	-0.1825	-0.0379	0.0225	0.0111	0.4221	2.7425***
	(0.7344)	(-0.4614)	(-0.7987)	(1.6574)	(1.0113)	(-1.3749)	(-0.3079)	(0.2148)	(0.0520)	(0.5499)	(2.7302)
ΔFDI	0.0044	-0.0032	-0.0036	-0.0027	-0.0020	-0.0024	-0.0035	-0.0047*	-0.0057***	-0.0130**	-0.0237***
	(0.7991)	(-0.7380)	(-0.9296)	(-1.3452)	(-1.0861)	(-1.0418)	(-1.2320)	(-1.7985)	(-2.9893)	(-2.6297)	(-2.6841)
ΔFINAN	0.1919**	0.0727	0.0468	-0.0094	0.0328	0.0107	0.0279	0.0336	0.0118	0.0851	0.4983**
	(2.4024)	(1.1586)	(0.7947)	(-0.1721)	(0.5078)	(0.1584)	(0.6989)	(0.9643)	(0.2473)	(0.6823)	(2.3719)

Note: 1) This table shows the results of the panel quantile regression model with different carbon emissions as dependent variables and FDI, economic growth, energy consumption and control variables as independent variables. 2) ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. 3) Figures in parentheses are t-values.

Regarding FDI, we can observe that the impact of FDI on carbon emissions is clearly heterogeneous. At the 5th quantile, the coefficient of ΔFDI is positive but insignificant at the 10% level. The positive coefficient of FDI is insufficient to support the pollution haven hypothesis in the low-emissions countries. However, other coefficients are negative and become significant at the high quantiles (70th, 80th, 90th and 95th quantile), implying that the influence of FDI on carbon emissions is negative and that the effect is more significant in high-emissions countries. These results support the halo effect hypothesis in high-emissions countries. FDI has an insignificant impact at low quantile, meaning that most FDI likely invests in non-polluting sectors in low-emissions countries. However, in high-emissions countries, may pay more attention to environmental problems, and their environmental regulations are stricter. Thus, in high-emissions countries, FDI inflow may help to develop managerial and specialized technological skills and innovations in the techniques of production; such technologies may also be indirectly passed on to domestic firms via backward or forward linkages. Multinational companies may also have more advanced technologies than their counterparts in these high-emission countries and will tend to disseminate cleaner technology that will be less harmful to the environment. Therefore, in high-emissions countries, an increase in FDI improves the regions' environmental quality. The results show that halo effect hypothesis is valid in high-emissions ASEAN-5 countries. Our results are similar to those of Atici (2012), who investigates the relationship between FDI and pollution by employing both random and fixed effects panel analyses in ASEAN countries. This author's results also support the halo effect hypothesis and provide no evidence for the FDI's deteriorating impact on environmental. However, this result cannot help us obtain a more complete picture of the factors that influence carbon emissions. In this paper, the results provide detailed description throughout the conditional distribution, especially in the countries with the most and least emissions. For example, at the 5th quantile, the coefficient of ΔFDI is positive but insignificant at the 10% level, which reminds low-emissions countries to prevent this region from becoming a pollution haven in the future. Similarly, our finding is consistent with the results of Asghari (2013), which support the halo effect hypothesis, although the study used MENA data, whereas ours focuses on ASEAN countries. In addition, Table 4 shows that the coefficients of ΔFDI are all negative and significant in the different OLS regression methods. This finding shows that the results under- or over-estimate the effect of factors. Therefore, it is inappropriate to use the OLS regression method to represent the relationships among variables.

Similarly, regarding economic growth, we can observe that the impact of economic growth on carbon emissions is also clearly heterogeneous. There are some significant differences across different percentiles in the conditional distribution of ΔCO_2. The coefficient of ΔGDP is highly significant and has a positive sign at various quantiles except for 95th quantile, which initially increases and then decreases along with the increase in the ΔCO_2 quantiles. At the 80th quantile, it becomes insignificant and then turns negative and become significant again at the 95th quantile. The coefficients of GDP2 are positive at all quantiles and are significant at the 90th and 95th quantiles. The quadratic term of GDP indicates that the relationship between economic growth and carbon emissions is monotonic in ASEAN-5, which implies that the EKC hypothesis is not applicable to the ASEAN-5 countries overall in the past. One possible explanation of this phenomenon is that ASEAN countries may not have achieved a desired level of income at the development stage. The findings of our study are in sharp contrast with those reported in earlier empirical studies (Ang, 2007; Apergis et al., 2009) and do not support the conventional wisdom of the EKC hypothesis that the level of environmental pollution first increases with income and then stabilizes and declines. However, our results are consistent with those of Narayan and Narayan (2010) and Chandran and Tang (2013). Overall, compared with previous research, these results provide not only evidence that tests the validity of EKC hypothesis but also a more complete picture of economic growth in pollution emissions. Specifically, our results show that the coefficient of ΔGDP is negative and significant at the 5% level for the 95th quantile, implying that a higher economic growth level can mitigate the increase in carbon emissions in high-emissions countries. Nevertheless, the coefficient of ΔGDP is insignificant and positive in the OLS mean regression with a two-way fixed effect. One possible explanation is that the results of our study are corrected for distributional heterogeneity, which could reduce the likelihood of under- or over-estimating the relevant coefficient. Additionally, the results provide evidence for our statement that OLS mean regression only provides an incomplete picture of the effect of economic growth on carbon emissions.

Furthermore, the coefficient of ΔENC is insignificant at lower and higher quantiles (the 5th, 20th, and 95th quantile) but significant in the OLS mean regression with a two-way fixed effect. Therefore, it is inappropriate to use the OLS mean regression method to represent the relationship between energy consumption and carbon emissions. Overall, the results imply that, as energy consumption increases by 1%, the level of carbon emissions increases by 0.046%~0.723%, which is consistent with our expectations because energy consumption is expected to cause more carbon emissions unless the country is utilizing mostly renewable sources of energy.

The other results for the control variables included in the model are also informative. First, we can observe the impact of the population size on carbon emissions. The coefficient of ΔPOP is clearly significant and positive at lower quantiles (the 5th, 10th, 20th, 30th and 40th quantile); at the 50th quantile, it becomes insignificant and then turns negative and becomes significant again at the higher quantiles (90th, 95th quantile), implying that a larger population size leads to higher carbon emissions in low-emissions countries whereas the opposite holds true in high-emissions countries. Second, the coefficient of ΔTRADE is negative and significant at the lower and higher percentiles, indicating that a higher level of trade openness can relieve carbon emissions in low- or high-emissions countries. Third, the results of ΔINDUS demonstrate that the share of the industry value added to GDP has a positive influence on carbon emissions in high-emissions countries. Finally, we can observe that the coefficient of ΔFINAN is significant only at the 5th and 95th quantiles and that its sign is positive except at the

30th quantile. The corresponding panel quantile regression diagrams are provided in Fig. 5.

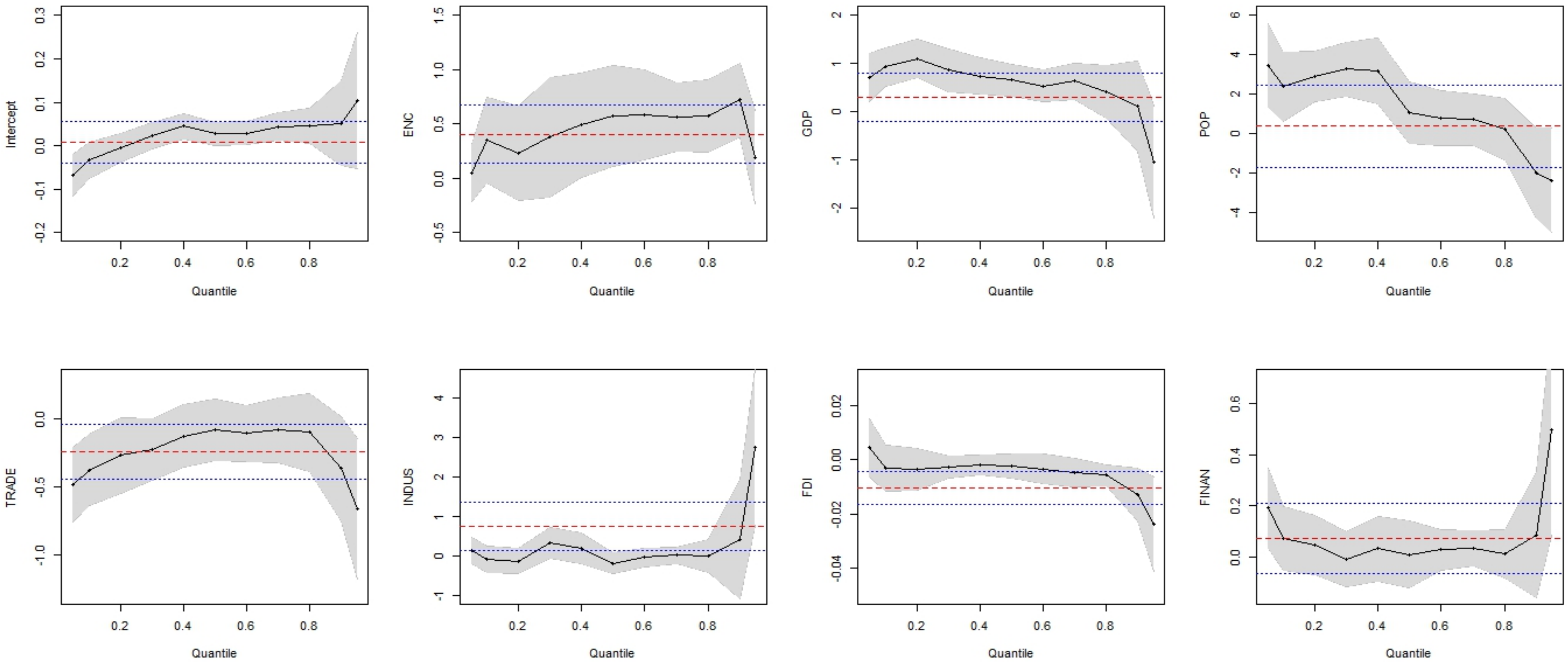

Fig. 5.Change in panel quantile regressions coefficients

Note: The red dashed line represents the corresponding OLS estimate with its 95% confidence interval (blue dashed line).

Finally, we must use inter-quantile tests to verify the heterogeneity of the parameters. Inter-quantile tests are developed to examine whether the differences along the estimated coefficients are significant across quantiles. In particular, following Koenker and Bassett (1982), Wald tests are performed to check for slope equality across quantiles. The variance-covariance matrixes of the corresponding coefficients are obtained from the bootstrap procedure. To save space, we present only the results concerning whether the model in the lower quantiles, herein represented by the 5th quantile, is the same as that in the middle quantiles (the 50th quantile) and in the higher quantiles (the 95th quantile). Table 7 presents the results of the test of equality of the coefficients between the lower quantiles and the upper quantiles, rejecting the hypothesis of parameter homogeneity except in the cases of ΔENC and ΔTRADE. Therefore, it is important to consider the distribution heterogeneity in studying the relationships among FDI, economic growth, energy consumption, financial development and carbon emission.

Table 7. Wald tests for the equality of slopes (0.05 against 0.5 and 0.95 quantiles)

	Against the 0.5 quantile		Against the 0.95 quantile	
	Test statistic	p-Value	Test statistic	p-Value
ΔENC	6.293**	0.012	0.341	0.559
ΔGDP	0.027	0.869	7.696***	0.005
ΔPOP	5.095**	0.024	8.750***	0.003
ΔTRADE	8.541***	0.003	0.378	0.538
ΔINDUS	1.695	0.193	6.203**	0.012
ΔFDI	1.463	0.226	3.660*	0.055
ΔFINAN	3.730*	0.053	1.635**	0.021

Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

In summary, by comparing the results of two methods, we can determine that panel quantile regression models provide a more complete picture of the factors that influence carbon emissions. In addition, based on the results, we can observe that the impacts of various factors on carbon emission are evidently heterogeneous. In particular, the effect of FDI supports the pollution haven hypothesis in low-emissions countries, whereas this effect supports the halo effect hypothesis in high-emissions countries. The impact of economic growth on carbon emissions is also clearly heterogeneous. The results indicate that a higher level of economic development can mitigate the increase in carbon emissions in high-emissions countries. Energy consumption increases carbon emissions, with the strongest effects occurring at the high end of the conditional distribution.

5.3 Robustness analysis

To test the validity of our results, in this section, we conduct two robustness checks. These include considering different values for λ and an alternative model specification.

First, we study whether our results are robust to different λ. We experiment with different values of λ ranging from 0.1 to 1.5. To save space, we present only the main variables of interest. The findings are reported in Table 8, and the results of the Wald tests, which are performed to check for slope inequality across quantile estimates, are reported in Table 9. The results are almost consistent with the results from the panel quantile regression with λ = 1. Second, Lee and Chang (2009) show that financial development indicators have a larger effect on economic growth than does FDI. Similarly, Ang (2009) argues that FDI and financial development are positively related to output in the long run. Given the relationship between these variables, we conduct two other model specifications. Specification I includes only FDI, and specification II includes only financial development. The results are reported in Tables 10 and 11, respectively. The findings are similar to those from the model specification including both variables. The corresponding Wald test results are presented in Table 12. The results show that there is a significant difference for the energy consumption variable when the model uses specification II. In addition, there is a significant difference for the economic growth variable between the 5th and 95th quantiles when the model uses specification I. In other words, the results from these two robustness checks largely support the robustness of the previous results.

Table 8. Robustness analysis: Alternative values of λ

Lambda		Quantile										
		0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
λ=0.1	ΔENC	0.042	0.368*	0.279	0.379	0.438*	0.523**	0.531**	0.544***	0.546***	0.732***	0.188
		(0.269)	(1.756)	(1.237)	(1.334)	(1.791)	(2.301)	(2.642)	(3.551)	(3.628)	(4.239)	(0.400)
	ΔGDP	0.734**	0.965***	1.042***	0.843***	0.746***	0.691***	0.734***	0.711***	0.485	0.142	-0.968*
		(2.382)	(4.397)	(5.031)	(3.833)	(4.468)	(4.391)	(3.987)	(3.474)	(1.639)	(0.301)	(-1.869)
	ΔFDI	0.004	-0.005	-0.005	-0.003*	-0.002	-0.002	-0.004	-0.004**	-0.006**	-0.012**	-0.024**
		(0.862)	(-1.129)	(-1.506)	(-1.868)	(-1.471)	(-0.956)	(-1.717)	(-2.185)	(-2.779)	(-2.167)	(-2.655)
λ=0.5	ΔENC	0.043	0.365	0.259	0.385	0.458*	0.572**	0.558***	0.562***	0.557***	0.728***	0.189
		(0.226)	(1.516)	(1.058)	(1.258)	(1.740)	(2.362)	(2.731)	(3.535)	(3.549)	(4.137)	(0.852)
	ΔGDP	0.723**	0.932***	1.064***	0.847***	0.732**	0.669***	0.584***	0.658***	0.446	0.142	-0.998
		(2.344)	(3.925)	(5.349)	(3.497)	(4.153)	(4.301)	(3.358)	(3.194)	(1.614)	(0.278)	(-1.725)
	ΔFDI	0.004	-0.003	-0.004	-0.003	-0.002	-0.001	-0.003*	-0.004*	-0.005**	-0.012**	-0.024**
		(0.834)	(-0.844)	(-1.232)	(-1.618)	(-1.047)	(-0.876)	(-1.749)	(-2.003)	(-2.915)	(-2.485)	(-2.584)
λ=0.9	ΔENC	0.045	0.356*	0.235	0.383	0.486**	0.579***	0.587***	0.566***	0.576***	0.722***	0.192
		(0.301)	(1.688)	(1.147)	(1.422)	(2.169)	(2.730)	(3.359)	(4.424)	(3.512)	(4.069)	(0.878)
	ΔGDP	0.713***	0.929***	1.101***	0.859***	0.743***	0.661***	0.532***	0.634***	0.414	0.133	-1.033*
		(2.795)	(4.428)	(5.804)	(4.176)	(4.159)	(3.898)	(3.174)	(3.405)	(1.421)	(0.272)	(-1.732)
	ΔFDI	0.004	-0.003	-0.003	-0.003	-0.002	-0.002	-0.003*	-0.004**	-0.005**	-0.013**	-0.023**
		(0.894)	(-0.800)	(-1.068)	(-1.235)	(-1.039)	(-1.332)	(-1.870)	(-2.324)	(-2.591)	(-2.419)	(-2.626)
λ=1.3	ΔENC	0.052	0.332	0.231	0.346	0.526**	0.526**	0.570***	0.559***	0.574***	0.724***	0.215
		(0.288)	(1.463)	(1.086)	(1.312)	(2.259)	(2.371)	(3.195)	(3.838)	(3.297)	(4.070)	(0.969)

	ΔGDP	0.720*** (2.906)	0.947*** (4.281)	1.103*** (5.686)	0.886*** (4.012)	0.734*** (3.915)	0.664*** (4.088)	0.545*** (3.316)	0.652*** (3.369)	0.409 (1.566)	0.091 (0.177)	-1.042* (-1.811)
	ΔFDI	0.004 (0.901)	-0.002 (-0.671)	-0.003 (-0.892)	-0.002 (-1.241)	-0.002 (-0.830)	-0.002 (-1.201)	-0.003 (-1.441)	-0.004** (-2.033)	-0.005** (-2.655)	-0.013** (-2.521)	-0.023** (-2.661)
λ=1.5	ΔENC	0.061 (0.248)	0.293 (1.057)	0.231 (0.871)	0.315 (1.104)	0.541* (2.212)	0.518** (2.258)	0.546*** (2.991)	0.555*** (3.913)	0.582*** (3.613)	0.726*** (3.881)	0.254 (1.122)
	ΔGDP	0.742*** (2.941)	0.964*** (3.946)	1.104*** (5.016)	0.893*** (3.791)	0.706*** (3.992)	0.649*** (4.111)	0.541*** (3.419)	0.661*** (3.297)	0.405 (1.456)	0.026 (0.050)	-1.033* (-1.735)
	ΔFDI	0.004 (0.359)	-0.002 (-0.454)	-0.003 (-0.706)	-0.003 (-1.530)	-0.002 (-1.071)	-0.002 (-1.383)	-0.003 (-1.484)	-0.005** (-2.028)	-0.005** (-2.092)	-0.013** (-2.479)	-0.022** (-2.462)

Note: 1) ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. 2) Figures in parentheses are t-values.

Table 9.Wald tests for the equality of slopes (0.05 against 0.5 and 0.95 quantiles): alternative values of λ

		ΔENC	ΔGDP	ΔPOP	ΔTRADE	ΔINDUS	ΔFDI	ΔFINAN
λ=0.1	τ=0.5	6.718***(0.009)	0.012(0.912)	3.226*(0.072)	8.786***(0.003)	1.808(0.178)	1.971(0.160)	4.534**(0.033)
	τ=0.95	0.502(0.478)	8.106***(0.004)	12.318***(0.000)	0.379(0.537)	7.371***(0.007)	5.079**(0.024)	1.911(0.167)
λ=0.5	τ=0.5	6.320**(0.012)	0.021(0.885)	3.505*(0.061)	9.088***(0.003)	1.640(0.200)	1.309(0.252)	4.828**(0.028)
	τ=0.95	0.398(0.528)	6.562**(0.010)	9.735***(0.001)	0.262(0.608)	6.847***(0.008)	4.040**(0.044)	1.523(0.217)
λ=0.9	τ=0.5	6.731***(0.009)	0.021(0.885)	4.995**(0.025)	8.593***(0.003)	2.285(0.131)	1.659(0.197)	5.461**(0.019)
	τ=0.95	0.342(0.559)	8.138***(0.004)	10.719***(0.001)	0.376(0.539)	6.881***(0.008)	3.923**(0.047)	1.935(0.164)
λ=1.3	τ=0.5	4.945**(0.026)	0.027(0.867)	7.376***(0.006)	8.197***(0.004)	1.243(0.264)	2.090(0.148)	2.305(0.128)
	τ=0.95	0.456(0.499)	9.081***(0.002)	12.113***(0.001)	0.471(0.492)	6.116**(0.013)	4.164**(0.041)	1.868(0.172)
λ=1.5	τ=0.5	5.354**(0.021)	0.069(0.792)	5.883**(0.015)	6.385**(0.011)	0.369(0.543)	1.761(0.185)	1.629(0.201)
	τ=0.95	0.736(0.391)	6.665***(0.009)	13.104***(0.000)	0.441(0.506)	5.982**(0.014)	3.779*(0.052)	1.687(0.193)

Note: 1) ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. 2) The numbers in parentheses are the p values for each estimation coefficient.

Table 10. Robustness analysis: Excluding FDI

	Quantile										
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
Constant	-0.057** (-2.583)	-0.044** (-2.314)	-0.011 (-0.531)	0.014 (1.058)	0.035*** (2.869)	0.036** (2.044)	0.035** (1.964)	0.034 (1.399)	0.032 (1.078)	0.055 (0.732)	0.084 (0.742)
ΔENC	0.111 (0.654)	0.196 (0.842)	0.209 (0.785)	0.400 (1.364)	0.504** (2.105)	0.648*** (2.929)	0.497*** (3.182)	0.506*** (3.333)	0.555*** (3.475)	0.510** (2.053)	0.635** (2.220)
ΔGDP	0.624** (2.384)	0.901*** (4.886)	1.109*** (5.192)	0.900*** (4.357)	0.748*** (4.152)	0.543*** (2.872)	0.599*** (3.763)	0.575*** (3.438)	0.450 (1.572)	0.229 (0.366)	-0.699 (-0.945)
ΔPOP	3.853*** (4.515)	2.201*** (3.289)	2.584*** (3.738)	2.711*** (4.284)	2.747*** (3.323)	1.814* (1.818)	0.973** (0.975)	0.466 (0.414)	-0.276 (-0.217)	-1.349 (-0.557)	-2.119 (-0.669)
ΔTRADE	-0.484*** (-3.183)	-0.407** (-2.627)	-0.286** (-2.011)	-0.273** (-2.089)	-0.128 (-0.966)	-0.134 (-1.034)	-0.107 (-0.877)	-0.087 (-0.674)	-0.162 (-0.950)	-0.307 (-1.382)	-0.465* (-1.752)

ΔINDUS	0.230 (1.171)	0.098 (1.827)	-0.149 (-0.908)	0.149 (0.831)	0.145 (0.680)	0.021 (0.111)	0.007 (0.046)	-0.019 (-0.138)	-0.005 (-0.027)	0.392 (0.529)	1.509 (1.116)
ΔFDI	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ΔFINAN	0.191* (1.833)	0.055 (0.825)	0.051 (0.837)	0.016 (0.301)	0.023 (0.406)	0.074 (1.041)	0.050 (0.984)	0.035 (0.833)	0.066 (0.816)	0.064 (0.448)	0.332 (0.160)

Note: 1) ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. 2) Figures in parentheses are t-values. 3) NA indicates that the variable is not included in the model.

Table 11. Robustness analysis: Excluding financial development

	Quantile										
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
Constant	-0.063*** (-2.893)	-0.038* (-1.953)	0.001 (0.054)	0.023 (1.410)	0.039*** (3.101)	0.029** (2.029)	0.027 (1.614)	0.044** (2.637)	0.048** (2.583)	0.062 (1.070)	0.122 (1.416)
ΔENC	0.096 (0.583)	0.284 (1.130)	0.210 (0.797)	0.361 (1.205)	0.569** (2.405)	0.576*** (2.876)	0.593*** (3.490)	0.544*** (4.211)	0.576*** (3.940)	0.693*** (3.811)	0.502** (2.565)
ΔGDP	0.747*** (3.089)	0.872*** (4.260)	1.160*** (4.837)	0.860*** (3.684)	0.688*** (3.840)	0.651*** (4.084)	0.559*** (2.837)	0.670*** (3.343)	0.449 (1.517)	0.244 (0.680)	0.397 (1.090)
ΔPOP	3.405*** (3.366)	2.595*** (3.389)	3.000*** (4.839)	3.306*** (4.529)	2.775*** (3.840)	1.179 (1.326)	0.626 (0.689)	0.694 (0.934)	0.323 (0.403)	-1.782 (-1.440)	-1.644 (-1.004)
ΔTRADE	-0.526*** (-3.067)	-0.427** (-2.366)	-0.227 (-1.434)	-0.227* (-1.773)	-0.114 (-0.770)	-0.088 (-0.613)	-0.096 (-0.785)	-0.060 (-0.483)	-0.087 (-0.581)	-0.343** (-2.020)	-0.258 (-0.975)
ΔINDUS	0.071 (0.416)	-0.004 (-0.025)	0.026 (0.153)	0.343 (1.557)	0.110 (0.516)	-0.172 (-0.955)	-0.108 (-0.737)	-0.050 (-0.532)	-0.018 (-0.108)	0.379 (0.494)	1.733* (1.671)
ΔFDI	0.002 (0.567)	-0.001 (-0.421)	-0.002 (-0.731)	-0.003 (-1.199)	-0.001 (-0.886)	-0.002 (-1.308)	-0.003* (-1.960)	-0.004** (-2.236)	-0.005** (-2.424)	-0.013** (-2.486)	-0.014* (-1.862)
ΔFINAN	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note: 1) ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. 2) Figures in parentheses are t-values. 3) NA indicates that the variable is not included in the model.

6. Conclusions and policy recommendations

The main aim of this study is to explore the impact of FDI, economic growth and energy consumption on carbon emissions. We use the panel quantile regression method to achieve the objectives. This method takes the unobserved individual heterogeneity and distributional heterogeneity into consideration. In addition, to avoid an omitted-variable bias, certain related control variables are included in the model. Compared with OLS mean regression, we believe that panel quantile regression models can help us obtain a more complete picture of the factors that affect carbon emissions. This study covers the annual sample period from 1981 to 2011 in five ASEAN countries.

The empirical results indicate that the impacts of various factors on carbon emission are evidently heterogeneous. In particular, the effect of FDI on carbon emissions is positive but insignificant at lower quantile, which does not lend sufficient support to the pollution haven hypothesis in lower-emission ASEAN countries. Nevertheless, the influence is negative in the middle- and high-emissions countries, which supports the halo effect hypothesis. These results are similar to those of Atici (2012), who believes that FDI benefits ASEAN countries in reducing pollution as a whole. Overall, we also find that energy consumption has a positive and significant effect on carbon emissions. Energy consumption increases carbon emissions, with the strongest effects observed at higher quantiles. Furthermore, this study also examines the validity of the EKC hypothesis in five ASEAN countries. The results indicate that the inverted U-shaped EKC hypothesis is not applicable to the ASEAN-5 economies as a whole. Our results are similar to those of Chandran and Tang (2013). However, the effect of economic growth is negative and significant in the uppermost quantile, which suggests that a higher level of economic growth can mitigate the increase in carbon emissions in high-emissions ASEAN countries. This conclusion is further confirmed by the Wald test, which is designed to examine whether the observed differences along the estimated coefficients are significant across quantiles. Similarly, the population size has a positive relationship with carbon emissions in low-emissions ASEAN countries, whereas the relationship is negative in high-emissions ASEAN countries. In addition, we find that trade openness has a negative influence on carbon emissions. In particular, the effect of trade openness is significant for low- and high- emissions countries. We do not find any significant effect of industrial structure on carbon emissions except at the uppermost quantiles. Another important finding is that a higher financial development level does not reduce carbon emissions in low- or high-emissions ASEAN countries. Finally, our results are generally robust for the different values of λ and when alternative model specifications are adopted.

Based on the results of the study, the following policy implications must to be pursued in to improve environmental quality in ASEAN countries. First, according to the pollution haven hypothesis and the halo effect hypothesis in different countries, host countries should attempt to assess the environmental impact of FDI before introducing foreign investors into the country. Moreover, high-emissions countries should improve the level of FDI. Second, in terms of energy consumption, energy is very important for development and poverty reduction. Each ASEAN country should consume energy effectively and have an energy development programme to shift from fossil fuels, such as oil, to clean and renewable energy, based on the existing condition of each country. Third, our findings suggest that high-emissions countries could benefit the most from increasing the levels of economic growth and population size. Among the low-emissions countries, higher economic growth and a greater population size do not appear to reduce carbon emissions. Therefore, high-emissions ASEAN countries should strengthen economic growth and improve their population size to reduce carbon emissions. Then, each ASEAN country should enhance trade openness; in particular, the effect of enhancing trade openness is clearer for low- and high-emissions ASEAN countries. Finally, the most important implication of our findings is that uniform carbon emissions control policies are unlikely to succeed equally across countries with different carbon emissions levels. Therefore, carbon emissions control measures should be tailored differently across low-emissions and high-emissions nations.

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