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Emissions and trade in Southeast and East Asian countries: a panel co-integration analysis

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Abstract

Purpose – The purpose of this paper is to analyse the implication of trade on carbon emissions in a panel of eight highly trading Southeast and East Asian countries, namely, China, Indonesia, South Korea, Malaysia, Hong Kong, The Philippines, Singapore and Thailand.

Design/methodology/approach – The analysis relies on the standard quadratic environmental Kuznets curve (EKC) extended to include energy consumption and international trade. A battery of panel unit root and co-integration tests is applied to establish the variables' stochastic properties and their long-run relations. Then, the specified EKC is estimated using the panel dynamic ordinary least square (OLS) estimation technique.

Findings – The panel co-integration statistics verifies the validity of the extended EKC for the countries under study. Estimation of the long-run EKC via the dynamic OLS estimation method reveals the environmentally degrading effects of trade in these countries, especially in ASEAN and plus South Korea and Hong Kong.

Practical implications – These countries are heavily dependent on trade for their development processes, and as such, their impacts on CO_2 emissions would be highly relevant for assessing their trade policies, along the line of the gain-from-trade hypothesis, the race-to-the-bottom hypothesis and the pollution-safe-haven hypothesis.

Originality/value – The analysis adds to existing literature by focusing on the highly trading nations of Southeast and East Asian countries. The results suggest that reassessment of trade policies in these countries is much needed and it must go beyond the sole pursuit of economic development via trade.

Keywords CO_2 emissions, Trade, Environmental Kuznets curve, Panel analysis

Paper type Research paper

1. Introduction

The past two decades have seen an expanding list of studies focusing on factors accounting for greenhouse gas (GHG) emissions. Among the various focuses, the environmental implications of trade have emerged to be a recurring and much-debated issue among especially advocates and opponents of trade liberalization. While the

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former emphasizes the environmental quality gains from trade, referred as the *gain-from-trade hypothesis*, the latter stresses on nations racing to the bottom of environmental quality in the pursuit of trade-led development, known as *the race-to-the-bottom hypothesis* (Frankel and Rose, 2005). These competing hypotheses are related to the theoretical ambiguity in the emission-trade relations arising from contradicting scale, technique and composition effects (Antweiler *et al.*, 2001). On one hand, the trade-led increase in an income may intensify public demand for cleaner environment and, with stringent environmental regulation, promotes the adoption of environmentally friendly production technology (technique effect) as well as results in the production composition shifts towards sectors that emit less GHGs (composition effect). On the other hand, trade stimulates the scale of production and accordingly emissions (scale effect), and for countries with lax environmental regulations, production shifts towards pollution-intensive goods (composition effect). Moreover, these countries would likely be the preferred locations of pollution-intensive industries, the so-called *pollution haven hypothesis*.

This theoretical ambiguity has stimulated growing empirical studies focusing on the relations between trade and environment. Early studies by Birdsall and Wheeler (1993) and Rock (1996) provide contrasting evidence on the impacts of trade on the environment. More specifically, while Birdsall and Wheeler (1993) find lower pollution intensity of production in countries with open trade policies, Rock (1996) demonstrates that open trading policies are a contributing factor to pollution. In an often-cited study by Antweiler *et al.* (2001), trade openness is found to be beneficial to the environment. More specifically, analysing SO_2 concentrations for a panel of 43 countries from 1971 to 2006, they find the technique and composition effects to outweigh the scale effect. Cole and Elliot (2003) find the net environmental effect of trade to depend on pollutants. While they document the beneficial effect of trade on biochemical oxygen demand (BOD) emissions, trade liberalization tends to increase NO_x and CO_2 emissions. Meanwhile, the effect of trade on SO_2 is found to be uncertain. Frankel and Rose (2005) use a 1990 cross-sectional sample of more than 35 countries and various measures of pollution. Accounting for endogeneity of income and trade, they find no evidence that trade is detrimental to the environment. Instead, trade can be beneficial particularly for SO_2.

Other studies, among which include Heil and Selden (2001) and more recently Managi *et al.* (2009), have emphasized differential emission effects of trade across countries. In their analysis of carbon emissions in 132 countries over the period 1950-1992, Heil and Selden (2001) document evidence suggesting the detrimental effect of trade intensity on carbon emissions in lower income countries and its beneficial effect in higher income countries. The recent analysis by Managi *et al.* (2009) focuses on pinpointing the environmental effects of trade across OECD and non-OECD countries. Based on a panel sample of 83 countries from 1980 to 2000, they find the effects of trade on BOD to be beneficial in both OECD and non-OECD countries. In line with Heil and Selden (2001), trade tends to decrease SO_2 and CO_2 in OECD countries and increase them in non-OECD countries[1].

In the present paper, we seek to contribute to this line of research by focusing on the experience of eight Southeast and East Asian countries, namely, China, Indonesia, South Korea, Malaysia, Hong Kong, the Philippines, Singapore and Thailand. These countries depend heavily on international trade as a core driver for economic development. They exhibit higher level of trade openness than the global average or at least experience tremendous growth in international trade. For instance, Malaysia, Hong Kong and Singapore record average trade ratios of more than 1, respectively 1.4, 2.4, and 3.5 over 1971-2009[2]. The trade ratio of Thailand has also surpassed one in recent years, while that of Korea and the Philippines is close to one. At the same time, China has exhibited drastic growth in its international trade. As the afore-mentioned studies demonstrate, pooling a large number of vastly heterogeneous countries may mask differential effects of trade on pollution across countries or groups of countries. Thus, by focusing on these highly trading nations, the environmental degradation/improvement from pursuing trade-led growth strategies would be more apparent.

The rest of the paper is structured as follows. Section 2 details the model and econometric approach. Then, Section 3 discusses estimation results. Finally, Section 4 concludes with the main findings.

2. Model and approach

In this section, we first explain model specification, which is based on the extension of the environmental Kuznets curve (EKC) regression. Given that the EKC depicts the evolution of emissions as countries develop, it is a long-run relation in nature. Hence, we first subject the data series a priori analyses using the panel unit root and co-integration tests to establish whether there is such a long-run relation between CO_2 emission and its determinants. Finally, we describe the model estimation procedure.

2.1 Model specification

In line with Halicioglu (2009), Jayanthakumaran *et al.* (2012), Kohler (2013) and Farhani *et al.* (2014), we adopt a log-quadratic EKC regression extended to include energy consumption and trade in the analysis. Expressing the regression in a panel setting, we have:

$$CO_{2it} = \beta_0 + \beta_1 y_{it} + \beta_2 y_{it}^2 + \beta_3 ec_{it} + \beta_4 tr_{it} + \varepsilon_{it} \qquad (1)$$

where CO_2 is carbon dioxide emissions per capita, y is real gross domestic product (GDP) per capita, y^2 is squared real GDP per capita, ec is energy consumption per capita and tr is international trade. All variables are expressed in natural logarithm. The EKC posits an inverse U-shaped relation between environmental degradation and economic development. That is, at the early stage of development, environmental quality worsens as a nation develops. Then, once the level of development passes a threshold point, the environmental quality improves. This is captured by making carbon emissions to be quadratic in real GDP per capita and hence the inclusion of y^2 in the model. Accordingly, it is expected that $\beta_1 > 0$ while $\beta_2 < 0$. The increase in energy consumption is likely to increase emissions and accordingly $\beta_3 > 0$. The parameter of interest is β_4 which, from the preceding discussion, cannot be signed a priori. Based on the *gain-from-trade hypothesis*, β_4 is expected to be negative. By contrast, *the race-to-the-bottom hypothesis* and the *pollution haven hypothesis* posit a positive relation between emissions and trade.

Given that the EKC is essentially a long-run curve (Cho *et al.*, 2014), we focus on estimating equation (1). To this end, we first verify that all of the variables are integrated of the same order, and they share a long run relationship or are co-integrated using a battery of panel unit root and panel co-integration tests. Then, with the finding of co-integration, we estimate equation (1) using the dynamic OLS (DOLS) estimator.

2.2 Panel unit root tests

With a long-time dimension of the data series, non-stationarity of the variables under study may render regression (equation [1]) spurious. Accordingly, as a priori analysis, we subject each variable to a battery of panel unit root tests developed by Levin *et al.* (2002), Im *et al.* (2003) and Maddala and Wu (1999), respectively, referred as Levin-Lin-Chin (LLC), Im-Pesaran-Shin (IPS) and Maddala-Wu (MW) unit root tests.

The LLC panel unit root test is based on the following equation:

$$\Delta z_{it} = \mu_i + \rho z_{it-1} + \sum_{j=1}^{k} \theta_{ij}\Delta z_{it-j} + \gamma_i t + \varepsilon_{it} \tag{2}$$

where z is a variable of interest, Δ is the first difference operator, k is the optimal lag order, t is a time trend and μ_i is a country-specific effect. In LLC panel unit test, the null hypothesis that z contains a unit root for all countries ($\rho = 0$) is tested against the alternative hypothesis that it is stationary for all countries ($\rho < 0$). Thus, the LLC test has a very restrictive assumption of homogenous ρ for all countries.

Both Im *et al.* (2003) and Maddala and Wu (1999) refine the panel unit root testing procedure by relaxing the assumption of homogenous autoregressive coefficient in the LLC test. With the null hypothesis that $\rho_i = 0$ for all i tested against the alternative hypothesis that $\rho_i < 0$ for some cross-sectional units, the IPS and MW tests do not require z to be stationary for all countries under the alternative hypothesis. The IPS test is based on averaging individual-augmented Dickey-Fuller (ADF) test statistics as:

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_{p_i} \tag{3}$$

Under the null of non-stationarity, the $\bar{t}$ is asymptotically normally distributed. Meanwhile, MW test is a Fisher type test combining the p-values of individual unit root tests as:

$$\lambda = -2\sum_{i=1}^{N} lnP_i \tag{4}$$

where P_i refers to the p-values from individual unit root tests, the ADF or PP tests. The MW test statistics follow a chi-square distribution with 2N degrees of freedom.

2.3 Panel co-integration tests

To analyse the presence of a long-run equilibrium that ties CO_2 to its determinants as given in equation (1), we conduct the widely used panel co-integration tests developed by Pedroni (1999). In addition, we also apply a panel extension of the Johansen's (1988) multivariate co-integration test by Larsson *et al.* (2001).

The Pedroni's co-integration test allows for parameter heterogeneity among the individual countries. It entails the estimation of equation (1) for each cross-sectional unit and the examination of the residuals' unit root property based on the following regression:

$$\varepsilon_{it} = \gamma_i \varepsilon_{it-1} + u_{it} \tag{5}$$

Pedroni (1999) suggests seven statistics to test the null hypothesis that the panel residuals contain a unit root, or the variables under study are not co-integrated. These statistics are panel v-statistic, panel rho-statistic, panel PP-statistic, panel ADF-statistic, group rho-statistic, group PP-statistic and group ADF-statistic. These seven statistics are asymptotically distributed as standard normal.

The first four statistics, normally referred as within-dimension, are based on pooling the residuals of the regressions and, accordingly, restrict the autoregressive coefficients in equation (5) to be the same across countries, that is $\gamma_1 = \gamma_2 = \ldots = \gamma_N = \gamma$. Meanwhile, the last three statistics, or between-dimension statistics, are based on averaging the individual autoregressive coefficients estimated for each country in the panel. This means that, while the within-dimension statistics assume homogeneity in the adjustment coefficients across countries, the between-dimension statistics allow adjustment coefficients to vary across countries. Among these panel co-integration test statistics, the panel ADF-statistic and the group ADF-statistic have been demonstrated via Monte Carlo simulation to have better small sample properties (Pedroni, 1999, 2004). Accordingly, given their relative reliability, we rely on these two test statistics as a basis of inference when there are conflicting signals from the co-integration test statistics.

As an additional test, the likelihood ratio co-integration test suggested by Larsson *et al.* (2001) is also applied. The test is based on the Johansen's (1988) co-integration framework. Namely, let $X = (CO_2, y, y^2, ec, tr)$, the panel error-correction model for N countries and T periods is written as:

$$\Delta X_{it} = \mu_i + \prod\nolimits_i X_{it-1} + \sum \Gamma_{ij} \Delta X_{it-j} + u_{it} \tag{6}$$

where Π is a $p \times p$ vector of the long-run matrix, the rank of which suggests the number of long-run relations. Based on equation (6), the test hypotheses are:

$$\begin{aligned} &H_0\colon rank\left(\prod\nolimits_i\right) \leq r_i;\ H_1\colon rank\left(\prod\nolimits_i\right) \leq p \\ &r_i = 0, 1, \ldots, p - 1, \text{ for all } i = 1, \ldots, N \end{aligned} \tag{7}$$

The test amounts to estimating equation (6) for each country using the maximum likelihood estimation method. Then, the panel test statistics are computed by averaging the individual country statistics.

2.4 Co-integrating equation

After affirming the presence of co-integration among the variables under study, the next step is to estimate equation (1) to address our main theme as to whether trade is environmentally improving or environmentally degrading. In the panel literature, various estimators have been proposed. These include, among others, panel OLS, pooled mean group, fully modified OLS (FMOLS) and DOLS. While the panel OLS estimation is "superconsistent", the endogeneity and serial correlation problems normally present in a long-run relationship render the OLS estimates bias. Further, as noted by Chen *et al.* (1999), even the bias-corrected OLS estimator generally provides no improvement. McCosky and Kao (1999) and Kao and Chiang (2000) demonstrate via Monte Carlo simulations that, among these estimators, the DOLS estimator exhibits less bias in small samples as compared to the panel OLS and FMOLS. The DOLS estimator also addresses the endogeneity and serial correlation problems parametrically by including leads and lags of first-differenced I(1) regressors. Banerjee (1999) also note the asymptotic equivalence between DOLS and FMOLS. In light of these, we adopt the DOLS in the analysis (Song *et al.*, 2008 and Li *et al.*, 2011).

Denote $Y = (y, y^2, ec, tr)$, the panel DOLS estimator is obtained from the following regression:

$$CO_{2it} = \varphi + \Phi Y_{it} + \sum_{k=-K_1}^{K_2} \pi_{ik} \Delta Y_{it+k} + w_{it} \tag{8}$$

where K_1 and K_2 are lag and lead orders, respectively, and Φ is a vector of long-run coefficients. It should be noted that, despite favourable small sample properties of the DOLS, it has a weakness. Namely, as noted by Li *et al.* (2011), the DOLS tends to be sensitive to the used lead and lag orders. Accordingly, following their work, we use alternative lead and lag orders for robustness.

3. Data and results

3.1 Data

The data used in this study are annual from 1971 to 2009 for eight Southeast and East Asian countries. These include China, Indonesia, South Korea, Malaysia, Hong Kong, the Philippines, Singapore and Thailand. We use CO_2 emissions expressed in metric tons per capita in the analysis. The level of development is captured by real GDP per capita in 2000 US dollar[3] while trade is measured by the ratio of trade (exports plus imports) to GDP. Finally, the energy consumption is per capita domestic energy use in kg of oil equivalent. These data series are sourced from World Development Indicators Database. In addition to a panel of eight economies (Panel I), we also examine the environmental implications of trade for two subsets of countries. First, it may be argued that China can exert significant influence on the results due to its size, rapid growth and drastic increase in energy use. Accordingly, we exclude China from the panel (Panel II). And second, in view of the attention given to ASEAN as a group by, for example, Lean and Smyth (2010), Chandran and Tang (2013) and Saboori and Sulaiman (2013), we also conduct the analysis for a panel of ASEAN-5 (Panel III).

As a preliminary look at our data, Figure 1 provides graphical representation over selected years, and Table I presents descriptive statistics of key variables, namely, CO_2 emissions per capita, real GDP per capita and trade ratio. From Figure 1 and Table I, we may observe quite substantial variations in carbon emissions per capita, real GDP per capita and trade ratio across the eight countries under study. In addition, the graphs tend to suggest close relations between the three variables with countries having high trade ratio and higher level of real GDP per capita to have relatively higher carbon emissions. However, an interesting aspect worth mentioning is that, although China has

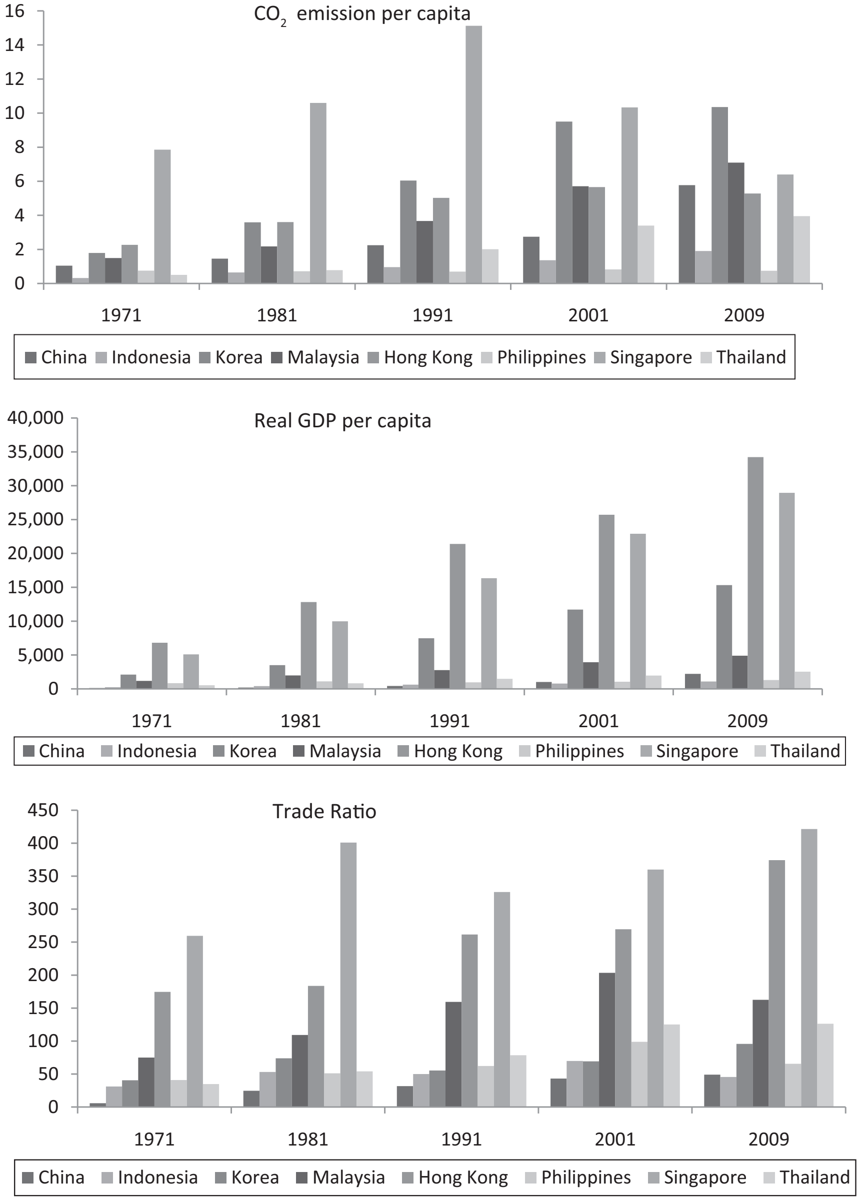

Figure 1.
CO$_2$ emission, real GDP and trade ratio

experienced tremendous growth in trade and real GDP, its trade ratio and real GDP per capita is relatively low as compared to many other countries. Yet, its carbon emissions are not the lowest. This may indicate that China can be distinct from the rest, which is addressed by excluding China from the sample[4].

Countries	CO_2 emissions (metric tons per capita)	GDP per capita (constant 2000 US $)	Trade (% of GDP)
China			
Mean	2.47	645.63	32.75
SD	1.25	577.30	18.64
Indonesia			
Mean	0.96	610.27	52.11
SD	0.43	249.81	11.16
Korea			
Mean	5.94	7,230.93	65.13
SD	2.99	4,296.62	11.75
Malaysia			
Mean	3.95	3,169.16	142.63
SD	2.22	2,306.05	49.39
Hong Kong			
Mean	4.61	18,978.09	243.03
SD	1.34	8,470.56	72.70
Philippines			
Mean	0.88	1,877.46	75.95
SD	0.73	5,315.82	54.06
Singapore			
Mean	12.20	16,535.91	345.87
SD	2.93	8,044.06	51.93
Thailand			
Mean	2.08	1,437.30	80.49
SD	1.37	690.81	36.87

Source: World Development Indicators Database by the World Bank

Table I.
Descriptive statistics of sample countries

3.2 Preliminary data analysis

As a preliminary analysis, we first conduct the LLC, IPS, MW-ADF and MW-PP panel unit root tests for each variable for the three panels of countries. In the tests, we include both the intercept and trend terms. The results of these tests are reported in Table II. These tests soundly suggest the I(1) property of all variables for all panels of countries. Accordingly, we proceed to the panel co-integration tests suggested by Pedroni (1999) and the Fisher's panel co-integration test developed by Larsson *et al.* (2001). In conducting the Pedroni's panel co-integration tests, we consider constant and constant and trend in the test equations and use the Schwartz information criterion for the test lag order. Meanwhile, in the Fisher's panel co-integration test, we consider lag orders of one and two and, as the results are similar, report only the latter case. These results are presented, respectively, in Table III and Table IV.

From Table III, we note some evidence for the presence of co-integration among the variables. More specifically, the panel ADF-statistic and the group ADF-statistic indicate the presence of co-integration in a panel of all eight countries as well as a panel

	LLC		IPS		MW-ADF		MW-PP	
Variables	Level	First difference	Level	First difference	Level	First difference	Level	First difference
Panel I: All countries								
LCO2	0.4362	−7.8754*	1.4107	−7.8564*	8.6982	87.7239*	6.9945	201.363*
LY	0.6141	−6.1477*	1.6597	−6.4920*	8.2852	69.8734*	7.0633	83.7147*
LY^2	0.6452	−5.8235*	1.6662	−6.3911*	6.8413	68.3935*	4.2091	80.6320*
LEC	1.9706	−4.3847*	2.4317	−7.3556*	5.9660	81.1757*	6.4574	339.324*
LTR	2.3149	−6.3606*	0.2780	−7.6679*	16.2912	83.3916*	15.7971	134.735*
Panel II: All countries – China								
LCO2	0.2008	−8.7591*	1.4584	−7.8712*	7.4924	82.5377*	6.5269	194.492*
LY	1.3252	−5.5804*	2.0204	−6.4305*	5.3847	64.8511*	2.9872	74.2120*
LY^2	1.3269	−5.1350*	1.5086	−6.2305*	6.3570	62.5174*	3.5504	72.9029*
LEC	1.3938	−5.3615*	1.9077	−7.4247*	5.9052	76.7699*	6.4271	329.699*
LTR	2.7674	−5.7875*	0.3996	−7.4197*	14.3153	75.7707*	15.3867	128.661*
Panel III: ASEAN								
LCO2	0.6058	−6.4842*	0.7864	−5.8318*	6.8639	51.4280*	6.4641	104.548*
LY	0.8807	−3.9811*	1.0867	−5.0765*	5.0353	43.1294*	2.6214	45.5007*
LY^2	0.8323	−3.8084*	0.6827	−4.9603*	5.9047	41.9751*	3.1869	44.6269*
LEC	1.2831	−2.7550*	1.2176	−5.8613*	3.9530	51.0149*	5.2234	127.009*
LTR	3.0452	−3.9737*	1.0279	−6.1574*	8.5461	53.0727*	9.2431	97.8576*

Notes: The values presented are test statistics. Both trend and intercept terms are included in the test equations; * denotes significance at 1% significance level; all countries are China, Indonesia, South Korea, Malaysia, Hong Kong, the Philippines, Singapore and Thailand. The ASEAN countries are Indonesia, Malaysia, the Philippines, Singapore and Thailand

Table II.
Panel unit root tests

of all countries minus China. The group PP-statistic further reaffirms the presence of co-integration in the panel of all countries when the constant and trend term are included in the test equation. In the case of the ASEAN-5 countries (Panel III), only the panel ADF-statistic from the test that includes both constant and trend terms suggests the long-run co-movement among the variables under study. Given the afore-mentioned discussion on the small sample properties of these tests, we incline to conclude in favour of co-integration. While the evidence for especially a group of ASEAN-5 from the Pedroni's test statistics is at best limited, the Fisher's panel co-integration test of Larsson *et al.* (2001) reported in Table IV provides a confirmation for the long-run co-movement among the variables. As may be observed from Table IV, both the trace and maximal eigenvalue statistics tend to suggest the presence of three long-run relations that tie these variables together. We view these results to be theoretically plausible, reflecting perhaps the long-run carbon emission equation, output equation and trade equation.

3.3 Model estimation

In light of the evidence for co-integration and our interest, we estimate the long-run carbon emission equation as given in equation (1) using the dynamic OLS estimation method. In the estimation, three alternative lead-lag orders are used for robustness. The results are reported in Table V. In a panel of all countries, i.e. Panel I, the signs of the

Table III. Panel co-integration tests

Panels	Within-dimension statistics Panel v-statistics	Panel rho-statistics	Panel PP-statistics	Panel ADF-statistics	Between-dimension statistics Group rho-statistics	Group PP-statistics	Group ADF-statistics
Panel I: All countries							
Constant	0.9075	1.4439	0.4829	−1.5683*	1.6907	−1.0664	−1.8165**
Constant + trend	0.7555	1.3089	−0.6970	−2.2125**	1.7291	−1.6372*	−2.2813**
Panel II: All countries – China							
Constant	0.8435	1.3719	0.4742	−1.4859*	1.6161	−1.1398	−1.9534**
Constant + trend	0.6918	1.2703	−0.5912	−2.0353**	1.9135	−1.2619	−1.9505**
Panel III: ASEAN							
Constant	0.6436	1.2405	0.6509	−1.1397	1.7460	1.0602	−0.0653
Constant + trend	0.5980	1.1221	−0.2613	−1.5265*	1.7969	0.3437	−0.2714

Notes: * and ** denote significance at 10 and 5 respectively; all countries are China, Indonesia, South Korea, Malaysia, Hong Kong, the Philippines, Singapore and Thailand. The ASEAN countries are Indonesia, Malaysia, the Philippines, Singapore and Thailand

	Hypothesized number of CE(s)				
Panels	None	At most one	At most two	At most three	At most four
Panel I: All countries					
Trace	147.2***	75.87***	34.81***	17.92	20.19
Max-eigen	89.49***	53.48***	28.88**	16.16	20.19
Panel II: All countries – China					
Trace	133.6***	69.81***	29.96***	15.16	14.05
Max-eigen	80.43***	51.14***	25.27**	14.99	14.05
Panel III: ASEAN					
Trace	107.1***	53.46***	21.70**	11.43	7.801
Max-eigen	68.07***	40.36***	17.71*	11.88	7.801

Notes: The lag orders are set to two; *, ** and *** denote significance at 10, 5 and 1%, respectively; all countries are China, Indonesia, South Korea, Malaysia, Hong Kong, the Philippines, Singapore and Thailand. The ASEAN countries are Indonesia, Malaysia, the Philippines, Singapore and Thailand

Table IV.
Fisher's panel co-integration test

estimated coefficients conform to the expectation. However, the results do not lend support to the EKC, as the coefficients of income and income squared are indistinguishable from zero. In addition, the evidence for the emission implications of trade is also limited. More specifically, the coefficient of the trade variable is significant only at 10 per cent significance level and only when both lead and lag orders are set to two. The only variable that appears to affect the emissions in Panel I is energy consumption. The energy consumption coefficient suggests a one-to-one relation between carbon emissions and energy consumption, i.e. a 1 per cent increase in energy consumption is associated with a 1 per cent increase in emissions.

It is possible that the foregoing results may be due to the inclusion of China, a large country with high growth performance and accelerated trade. As Figure 1 and Table I indicate, China is quite distinct from the rest of the countries. That is, while China has exhibited high growth performance and accelerated trade, its level of development and trade ratio is low relative to other countries. Dietzenbacher *et al.* (2012) have further highlighted that the myth of increasing trade of China is at the cost of environment. They argue that more than half of increased export of China is processing exports. Their findings suggest that Chinese carbon emission are overestimated by more than 60 per cent if the distinction between processing exports and normal exports is not made. Moreover, Jalil and Mahmud (2009) and Jayanthakumaran *et al.* (2012) find trade to be insignificantly related to carbon emissions for China. Accordingly, we exclude China from the panel. In addition, we also focus on a group of ASEAN-5 countries. The results reported in Table V (Panels II and III) provide indication that China may be different, as the estimated coefficients for output and trade substantially change once China is excluded from the panel. In line with the results from Panel I, the energy use remains significant in explaining carbon emissions, and its coefficients are largely similar. However, in Panels II and III, we find supportive evidence for the EKC as reflected by the significant positive coefficient of income and negative coefficient of income squared. Most importantly, by excluding China from the panel, the trade coefficients turn

Table V. Dynamic OLS estimation results

Panel	Lags	Leads	Long-run coefficients LY	 LY2	 LEC	 LTR
Panel I: All countries	2	1	0.3161 (0.419)	−0.0180 (0.487)	1.0891 (0.000)***	0.1369 (0.110)
	2	2	0.2304 (0.567)	−0.0130 (0.625)	1.0979 (0.000)***	0.1539 (0.081)*
	1	1	0.2958 (0.437)	−0.0171 (0.496)	1.1049 (0.000)***	0.1213 (0.145)
Panel II: All countries – China	2	1	1.6878 (0.002)***	−0.0960 (0.002)***	0.8889 (0.000)***	0.2468 (0.012)**
	2	2	1.5589 (0.005)***	−0.0886 (0.006)***	0.9018 (0.000)***	0.2580 (0.011)**
	1	1	1.7082 (0.001)***	−0.0973 (0.001)***	0.8958 (0.000)***	0.2409 (0.012)**
Panel III: ASEAN	2	1	1.2157 (0.016)**	−0.0858 (0.009)***	0.9708 (0.000)***	0.5323 (0.000)***
	2	2	1.0694 (0.040)**	−0.0755 (0.025)**	0.9458 (0.000)***	0.5482 (0.000)***
	1	1	1.2475 (0.011)**	−0.0841 (0.008)***	0.9364 (0.000)***	0.5196 (0.000)***

Notes: The figures represent the estimated coefficients of Model 1 and the numbers in parentheses are p-values; *, ** and *** denote significance at 10, 5 and 1%, respectively; all countries are China, Indonesia, South Korea, Malaysia, Hong Kong, the Philippines, Singapore and Thailand. The ASEAN countries are Indonesia, Malaysia, the Philippines, Singapore and Thailand significant at better than 5 per cent significance level. This result lends support to the view that trade is harmful to the environment and suggests indirectly the dominance of scale effect over the technique effect. From the estimated coefficients, we may conclude that the pollution effect of trade tends to be more severe in the ASEAN-5 countries (Panel III). Namely, in these countries, an increase in the trade ratio by 10 per cent is related to the increase in expected carbon emissions by roughly 5.2-5.5 per cent in the long run. While adding Hong Kong and South Korea into the ASEAN panel (i.e. Panel II) also yields positive and significant trade coefficient, its magnitude drops substantially.

Our results have important implications. On the basis of Panel II estimation results, the yearly income threshold point is computed to be roughly USD 6,500[5]. In the group of these countries, only Hong Kong, Singapore and South Korea have surpassed this threshold point. For the remaining countries, i.e. Indonesia, Malaysia, the Philippines and Thailand, environmental degradation is likely to be a by-product of their pursuits of economic progress. Still, the EKC (or the quadratic relation between emissions and income) can be shifted downward if trade is environmentally improving. Our finding that trade is environmentally degrading urges policy-makers of these nations to relook at their trade policies and production technologies. As these nations are generally highly dependent on imported capitals and intermediate goods, perhaps a requirement or incentive should be put in place to encourage the imports of more environmentally friendly technologies. In short, support and regulatory mechanisms such as incentives and tax holidays for the adoption of environmentally friendly technologies are required. Moreover, the finding that trade has adverse bearings on the environment tends to hint on the lax of environmental regulations, an area that needs immediate attention. In other words, enforcement mechanisms in terms of taxes and penalties must be in heightened.

4. Conclusion

The trade-led development and its potential implications on the environment has come under close scrutiny and solicited intense debate among advocates and opponents of trade liberalization. In this paper, we shed light on this debate by evaluating the relations between carbon emissions and trade for a group of highly trading Southeast and East Asian countries. The analysis is based on a log-quadratic EKC extended to include energy consumption and trade. Viewing the curve to represent a long-run relation, we adopt a panel co-integration approach in the analysis. The results we obtained indicate the validity of the extended EKC as a long run or co-integrating equation. Using a panel DOLS estimator, we find evidence for the environmentally degrading effects of trade in these countries, especially when China is excluded from the panel. The analysis further reveals a more damaging environmental effect of trade for ASEAN-5 countries. While the present paper does not estimate the various effects of trade, i.e. scale, technique and composition effects, the results tend to suggest that these countries may have compromised the environment in their pursuit of trade-led development. Hence, a relook at trade policies by respective countries seems needed to ameliorate the adverse bearings of trade on the environment. To this end, the focus on environmentally friendly technologies via imported capitals and improvement of environmental regulations could be potentially useful.

Notes

1. Many studies have also evaluated the experience of individual countries by focusing specifically on the impact of trade or trade liberalization on emissions or by including trade as a controlled variable in their analysis of the EKC. These include Halicioglu (2009), Yunfeng and Laike (2010), Jayanthakumaran *et al.* (2012), Tiwari *et al.* (2013) and Shahbaz *et al.* (2012, 2013a, 2013b), to name a few.
2. The trade ratio is the summation of exports and imports as a ratio of real GDP, which is taken from the World Bank's World Development Indicators. The average trade ratio is computed over the period 1971-2009.
3. Dollar figures for GDP are converted from domestic currencies using 2000 official exchange rates.
4. China also has vast green and agricultural territorial extension, which further adds to the fact that China may be distinct from the rest. We thank a referee for raising this point.
5. The income threshold refers to the income cut-off point beyond which the increase in real income per capita brings environmental benefit, as posited by the EKC. It is computed from equation (1) by solving $\partial CO_2/dy = \beta_1 + \beta_2 y = 0$ and taking the antilog of y.

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