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CO₂ emissions, urbanisation and economic growth: evidence from Asian countries

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ABSTRACT

This paper empirically examines the dynamic causal relationships between CO₂ emissions, energy consumption, economic growth, trade openness and urbanisation for the period 1980–2014 using the pooled mean group (P.M.G.) approach and panel Granger causality tests for Asian countries. Using panel unit root tests we found that all variables integrated of order 1. From the Pedroni panel cointegration test, there is a long-run relationship among the variables. The results showed that urbanisation increases energy consumption and CO₂ emissions. Environmental quality is considered a normal good in the long run. The Granger causality test results support that there is a bidirectional causal relationship between economic growth, urbanisation and CO₂ emissions. Consumption is greater than the impact on CO₂ emissions in the eastern region and some evidence supports the compact city theory. These results contribute not only to advancing the existing literature, but also deserve special attention from policymakers and urban planners in Asian countries.

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1. Introduction

With the acceleration of urbanisation, urban areas play a major role in energy consumption and CO₂ emissions in Asian countries. The impact of urbanisation on energy use of fossil fuels has unequivocally disturbed and increased the carbon levels in the atmosphere, causing warming. This process leads to global warming and climate change. The Intergovernmental Panel on Climate Change (I.P.C.C.) report of 2007 reveals that there is a strong link between global average temperature and greenhouse gas (G.H.G.) emissions. For instance, G.H.G. emissions have increased about 1.6% per year, with CO₂ emissions from fossil fuels at about 1.9% per year over the last three decades. The I.P.C.C. also reported that the global average temperature is expected to increase between 1.1 and 6.4 °C over the next 100 years.

CO₂ emissions from energy consumption have increased significantly in newly industrialised countries since the 1990s compared with industrialised countries.

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The environmental deterioration has reached alarming levels and has raised concerns about global warming and climate change. As a result, understanding of the reasons for environmental degradation and its relationship with economic growth has become increasingly important in recent years. The effects of economic growth on the environment have become a common area of research among economists. Two parallel literatures on the relationship between economic growth and environmental pollution have emerged.

Urbanisation is a dynamic moderation phenomenon on the social and economic capability of the rural areas (agrarian economic base) to urban areas (industrial economic base). However, urbanisation and high urban densities were expected in recent decades, due to economic globalisation; many developing countries are undergoing economic transformation that ultimately leads to the physical expansion of urban areas. However, the rapid wave of urbanisation over the last few decades has seen the potential for increased energy demand and severe environmental concerns, simultaneously.

The rate of urbanisation in Africa and Asia is relatively fast, with the percentage of the urban population expected to double between 2000 and 2030. Overall, the global urban population, which was 1.52 billion in 1970, is expected to reach 4.6 billion people by 2030 and a large part of this will be in Asian and African cities. Urban areas may also be expected to be energy intensive, with a strong trend in economic activities (i.e., industrial manufacturing and transportation) that are mainly fossil fuel-driven and cause environmental degradation. Malaysia is a resource-rich and culturally diverse country in East Asia. For the past three decades, urban growth has been one of the main goals of this country's economic development.

Statistics on CO₂ emissions, energy consumption, per capita real gross domestic product (G.D.P.), trade openness and urbanisation are presented in [Table 1](#). The CO₂ emission rates in Bahrain are the highest and Bangladesh has the lowest CO₂ emissions growth at -1.63 and 3.13, respectively. In addition, Bahrain has the highest rate and Bangladesh has the lowest energy consumption growth at 4.94 and 9.25, respectively. Based on per capita real G.D.P. rate, Japan has the highest per capita G.D.P. growth, while Bangladesh is the poorest country on this panel. Growth in Japan is 10.35 and in Bangladesh is 6.01. Regarding the trade openness rate, Malaysia is the highest, while Japan has the lowest, at 5.04 and 3.15, respectively. Finally, the urbanisation growth ranges from 2.91 in Sri Lanka to 4.48 in Bahrain.

An overview of urbanisation reveals migration from rural areas to cities, a phenomenon associated with many parameters: household size, changing industrial structure, new housing and public facilities, city size distribution, etc. Basically, urbanisation creates upward pressure on energy consumption and CO₂ emissions (Niu & Lekse, 2017).

As rapid industrialisation and urbanisation lead to increase CO₂ emissions in Asian countries, many researchers have conducted extensive studies on the effects of industrialisation and urbanisation on CO₂ emissions from a national perspective without consideration for regional differences. CO₂ emissions are affected by regional features, whether at the overall or per capita level. Researchers investigating the impacts of industrialisation or urbanisation on CO₂ emissions only from a national

Table 1. Descriptive statistics of the variables for the selected Asian countries.

| | | Mean. | Min. | Max. | St. Deviation |
|------------------|------------------|-----------|-----------|-----------|---------------|
| Bahrain | LCO ₂ | 3.134231 | 2.802405 | 3.393784 | 0.169000 |
| | LENC | 9.254923 | 8.961173 | 9.409555 | 0.119377 |
| | LGDP | 9.720828 | 9.509484 | 9.831989 | 0.101176 |
| | LTR | 5.054615 | 4.747375 | 5.526006 | 0.212610 |
| Bangladesh | LURBAN | 4.477691 | 4.455521 | 4.485474 | 0.008225 |
| | LCO ₂ | -1.631338 | -2.370869 | -0.859034 | 0.481799 |
| | LENC | 4.941240 | 4.630405 | 5.428418 | 0.243334 |
| | LGDP | 6.011123 | 5.650951 | 6.616562 | 0.268594 |
| China | LTR | 3.289109 | 2.814678 | 3.873509 | 0.338110 |
| | LURBAN | 3.120139 | 2.698067 | 3.512023 | 0.227925 |
| | LCO ₂ | 1.110419 | 0.378732 | 2.119112 | 0.506204 |
| | LENC | 6.905340 | 6.392781 | 7.785840 | 0.429028 |
| India | LGDP | 6.809986 | 5.396705 | 8.259178 | 0.878660 |
| | LTR | 3.517479 | 2.527572 | 4.170834 | 0.446850 |
| | LURBAN | 3.494501 | 2.963106 | 3.996548 | 0.314150 |
| | LCO ₂ | -0.010933 | -0.693243 | 0.623331 | 0.379694 |
| Indonesia | LENC | 6.038372 | 5.684402 | 6.505992 | 0.233401 |
| | LGDP | 6.290293 | 7.117975 | 5.678611 | 0.437047 |
| | LTR | 3.195036 | 2.485629 | 4.017194 | 0.521761 |
| | LURBAN | 3.303134 | 3.139746 | 3.477108 | 0.097785 |
| Iran | LCO ₂ | 0.155223 | -0.442156 | 0.846988 | 0.405834 |
| | LENC | 6.428251 | 5.934046 | 6.808825 | 0.295260 |
| | LGDP | 6.926430 | 6.307012 | 7.524997 | 0.355049 |
| | LTR | 3.975004 | 3.688226 | 4.566286 | 0.164218 |
| Iraq | LURBAN | 3.599767 | 3.095759 | 3.970349 | 0.273038 |
| | LCO ₂ | 1.592950 | 1.033185 | 2.093652 | 0.351103 |
| | LENC | 7.453629 | 6.889725 | 8.006365 | 0.378425 |
| | LGDP | 7.906986 | 7.558719 | 8.256047 | 0.193065 |
| Japan | LTR | 3.633696 | 2.649351 | 4.026313 | 0.314652 |
| | LURBAN | 4.114589 | 3.905864 | 4.288471 | 0.117457 |
| | LCO ₂ | 1.224199 | 0.751915 | 1.787624 | 0.229111 |
| | LENC | 7.006668 | 6.525006 | 7.501317 | 0.273523 |
| Jordan | LGDP | 7.369874 | 6.528331 | 7.850635 | 0.311061 |
| | LTR | 3.360691 | -3.863269 | 5.038474 | 2.394319 |
| | LURBAN | 4.229823 | 4.182371 | 4.249523 | 0.014137 |
| | LCO ₂ | 2.189037 | 2.002977 | 2.341066 | 0.097995 |
| Korea | LENC | 8.185579 | 7.945866 | 8.316718 | 0.124361 |
| | LGDP | 10.35153 | 9.950510 | 10.53463 | 0.174892 |
| | LTR | 3.146945 | 2.767827 | 3.662030 | 0.256497 |
| | LURBAN | 4.398464 | 4.333033 | 4.532825 | 0.069165 |
| Malaysia | LCO ₂ | 1.191661 | 0.773457 | 1.359659 | 0.124483 |
| | LENC | 6.951497 | 6.548197 | 7.149549 | 0.125847 |
| | LGDP | 7.685881 | 7.383257 | 7.964926 | 0.166218 |
| | LTR | 4.800091 | 4.404760 | 5.006985 | 0.131070 |
| Oman | LURBAN | 4.326265 | 4.094828 | 4.424212 | 0.096749 |
| | LCO ₂ | 2.001304 | 1.263463 | 2.561425 | 0.409459 |
| | LENC | 7.956748 | 6.953124 | 8.569476 | 0.544378 |
| | LGDP | 9.376139 | 8.275315 | 10.10910 | 0.563651 |
| Pakistan | LTR | 4.218323 | 3.884822 | 4.700481 | 0.231172 |
| | LURBAN | 4.316007 | 4.038127 | 4.411100 | 0.111205 |
| | LCO ₂ | 1.509758 | 0.705006 | 2.0778089 | 0.475719 |
| | LENC | 7.461833 | 6.771793 | 8.007103 | 0.408775 |
| Oman | LGDP | 8.338908 | 7.748569 | 8.904527 | 0.363659 |
| | LTR | 5.050917 | 5.395477 | 4.654504 | 0.244553 |
| | LURBAN | 4.044454 | 3.738717 | 4.304200 | 0.180979 |
| | LCO ₂ | 2.218927 | 1.491973 | 3.411322 | 0.531077 |
| Pakistan | LENC | 7.993385 | 6.688292 | 8.981327 | 0.670192 |
| | LGDP | 9.338280 | 9.562429 | 8.847161 | 0.168331 |
| | LTR | 4.479796 | 4.170917 | 4.863315 | 0.148056 |
| | LURBAN | 4.207683 | 3.862034 | 4.346114 | 0.133701 |
| LCO ₂ | -0.346053 | -0.889775 | 0.054636 | 0.278122 | |

(continued)

Table 1. Continued.

| | | Mean. | Min. | Max. | St. Deviation |
|--------------|------------------|-----------|-----------|-----------|---------------|
| Philippines | LENC | 6.059254 | 5.759340 | 6.260092 | 0.145452 |
| | LGDP | 6.397049 | 6.006648 | 6.701600 | 0.197943 |
| | LTR | 3.528643 | 3.336823 | 3.661238 | 0.075005 |
| | LURBAN | 3.481723 | 3.334559 | 3.645528 | 0.090626 |
| | LCO ₂ | -0.257590 | -0.661011 | -0.026138 | 0.166157 |
| Saudi Arabia | LENC | 6.126970 | 6.032352 | 6.240546 | 0.054565 |
| | LGDP | 9.522757 | 6.810315 | 7.415822 | 0.163324 |
| | LTR | 4.258770 | 3.826662 | 4.684446 | 0.278154 |
| | LURBAN | 3.820188 | 3.623834 | 3.883418 | 0.067748 |
| | LCO ₂ | 2.682980 | 2.325272 | 2.943261 | 0.153205 |
| Sri Lanka | LENC | 8.450200 | 8.051139 | 8.987140 | 0.223356 |
| | LGDP | 7.018571 | 9.348854 | 9.967434 | 0.165839 |
| | LTR | 4.315026 | 4.033784 | 4.565417 | 0.148605 |
| | LURBAN | 4.351512 | 4.187531 | 4.417949 | 0.061434 |
| | LCO ₂ | -0.911765 | -0.271894 | 0.443022 | -0.911765 |
| Thailand | LENC | 5.956714 | 5.728429 | 6.317733 | 0.186698 |
| | LGDP | 6.871489 | 6.298037 | 7.629951 | 0.393107 |
| | LTR | 4.129127 | 2.513723 | 4.484543 | 0.417291 |
| | LURBAN | 2.916899 | 2.906737 | 2.932739 | 0.006920 |
| | LCO ₂ | 0.837500 | -0.262026 | 0.630646 | 0.837500 |
| Vietnam | LENC | 6.885973 | 6.020285 | 7.585600 | 0.505825 |
| | LGDP | 7.632067 | 6.842129 | 8.234509 | 0.439733 |
| | LTR | 4.492545 | 3.858295 | 4.944759 | 0.378852 |
| | LURBAN | 3.504063 | 3.895365 | 3.288066 | 0.186396 |
| | LCO ₂ | -0.424791 | -1.308136 | 0.863108 | 0.712040 |
| | LENC | 5.943817 | 5.584752 | 6.693117 | 0.369108 |
| | LGDP | 6.148455 | 5.508157 | 6.982778 | 0.493384 |
| | LTR | 4.332155 | 2.941830 | 5.133057 | 0.679446 |
| | LURBAN | 3.166834 | 2.957355 | 3.495022 | 0.178877 |

Source: WDI (World Development Indicators) online database, 2015.

point of view ignore the effects of regional differences, leading to biased estimations. Considering these problems, we are conducting a regional analysis of CO₂ emissions and urbanisation.

The main objectives of this paper are to study the relationship between CO₂ emissions, energy consumption and income for a panel of Asian countries during the period 1980–2014 and to produce new evidence on the economic growth and environment nexus. Therefore, a test of the relationship between income and environment for these countries could reveal important information on this issue. Secondly, very few studies include trade in the relationship as an additional variable. This study also provides information on the impact of trade openness on the CO₂ emissions for Asian countries. This could also solve the problem of omitted variable biases encountered by earlier studies.

Finally, to our knowledge, this is the first study that includes urbanisation in the relationship between income and environment. Overall, this paper examines the dynamic relationship between CO₂ emissions, energy consumption, income, trade openness and urbanisation.

The rest of the paper is organised as follows. [Section 2](#) refers to literature on the effects of urbanisation and economic growth on CO₂ emissions. [Section 3](#) discusses the data and the model. [Section 4](#) explains the methodology and the results of the estimates and [Section 5](#) concludes with a summary of the findings and policy implications.

2. Literature review

The theory of ecological modernisation details how urbanisation is a process of social transformation which is an important indicator of modernisation. As societies evolve from low to middle-stage development, economic growth takes precedence over environmental sustainability. As societies continue to evolve into higher stages of development, environmental damage becomes more important and societies look for ways to become more environmentally sustainable. The adverse effects of economic growth on the environment may be reduced by technological innovation, urbanisation and the shift from a manufacturing economy to a service economy (Gouldson & Murphy, 1997; Mol & Spaargaren, 2000).

The relationship between urbanisation and CO₂ emissions has been investigated extensively in recent years. The empirical results have been mixed. Ehrhardt-Martinez, Crenshaw and Craig (2002) argued that urbanisation is a good proxy for modernisation and therefore the relationship between urbanisation and CO₂ emissions may vary from country to country, finding an inverted U-shaped relationship between urbanisation and CO₂ emissions.

To explore a clear relational structure between urbanisation and CO₂ emissions, Baltagi and Li (2002) investigated this topic using a semi-parametric panel fixed-effects regression model. Similarly, using panel data, York, Rosa and Dietz (2003) used a cross-section of 137 countries to test a relationship between urbanisation and CO₂ emissions. They showed that increased urbanisation leads to increase CO₂ emissions. Cole and Neumayer (2004) used a panel of 86 countries to empirically examine the relationship between urbanisation, other demographic factors and environmental quality. Their findings showed that urbanisation has a positive effect on increasing CO₂ emissions.

For European Union member countries, Martinez-Zarzoso, Bengochea-Morancho and Morales-Lage (2007) studied the effect of population growth on CO₂ emissions during the period 1975–1999. Their results indicated that population growth is positively linked to the increase of CO₂ emissions and that environmental impacts are lower in relatively developed member countries.

Poumanyong and Kaneko (2010) argued that the hypothesis that the relationship between urbanisation and CO₂ emissions is homogenous for all countries may be unreasonable. They examined the effects of urbanisation on CO₂ emissions for low-, middle- and high-income groups and found that while a positive relationship exists for all income groups, it is most prominent in the middle-income group. However, using the semi-parametric panel data model, Liddle and Lung (2010) used a panel data set of 17 developed countries followed during 10 5-year periods; they found a positive but insignificant impact of urbanisation on CO₂ emissions when an aggregate for emissions was used as the dependent variable. Urbanisation has a positive and statistically significant impact on CO₂ emissions when CO₂ from transport was used as the dependent variable using a sample of Group of 7 (G7) countries.

Fragkias, Guneralp and McDonald (2013) showed that large cities are not more emissions-efficient than smaller ones, because large cities are not more energy-efficient than smaller ones. However, Barla, Miranda-Moreno and Lee-Gosselin (2011) and Liu and John (2012) reached the opposite conclusions: the compact city scenario

should reduce energy consumption and CO₂ emissions per household compared with the dispersed city scenario.

Energy plays a key role in sustainable development. There are a number of studies that have attempted to find the direction of causality between energy, income and environmental degradation, but the results are mixed and country-specific. As a result, the studies incorporate urbanisation and energy consumption variables into models to explore potential Granger causality from urbanisation to CO₂ emissions.

Some research has also paid attention to these problems at the city level. In the Lahore Metropolitan Area of Pakistan, urbanisation has boosted energy consumption and G.H.G. emissions due to the reduction of agriculture areas (Ali & Nitivattananon, 2012). However, the opposite effect has emerged in Canadian cities, where higher urban density has reduced energy consumption (Larivière & Lafrance, 1999). Newman and Kenworthy (1989) and Dodman (2009) had similar results; they both found a strong inverse relationship between urban density and transport per capita energy consumption. In terms of household-level analysis, Pachauri and Jiang (2008) showed that total energy consumption in rural households exceeded that of urban households in India. However, a positive relationship between urbanisation and total household energy consumption has been found in north-east Thailand (Nansaior, Aran Patanothai, Terry, & Suchint, 2011).

In recent years, Halicioglu (2009) used Turkish data, also integrating trade into CO₂ emissions, income and energy consumption for empirical analysis. Their analysis revealed that for the Turkish economy, income is the most crucial determinant of CO₂ emissions, followed by energy consumption and finally trade. They found two types of relationships among these variables, where one type of relationship revealed that CO₂ emissions are determined not only by energy consumption and income, but also by trade. The second type of relationship has shown that CO₂ emissions, energy consumption and foreign trade all play an important role in determining Turkey's income level. Hossain (2011) used a multivariate causality analysis to investigate the dynamic relationship between emerging industrialised countries and to find a positive causality relationship from urbanisation to CO₂ emissions.

Madlener and Sunak (2011) found that various mechanisms of urbanisation led to a substantial increase in energy consumption and that the relevance of these mechanisms varied between developing and developed countries. With the Stochastic Impacts by Regression on Population, Affluence and Technology (S.T.I.R.P.A.T.) model, Martínez-Zarzoso et al. (2007) analysed the impact of urbanisation on CO₂ emissions in developing countries from 1975 to 2003 and three groups of countries in which the impact of urbanisation differs considerably, taking into account the heterogeneity in the country sample.

For seven regions of the world, Al-mulali, Sab and Fereidouni (2012) explored the long-run bidirectional relationship between the variables and discovered a positive relationship in 84% of the countries studied. They used the panel model to study the nexus between variables for the Middle East and North Africa countries, finding evidence of long- and short-run bidirectional causalities between the urbanisation and CO₂ emissions variables. Also, based on the dynamic Ordinary Least Squares test, the

significance and magnitude of urbanisation elasticities for CO₂ emissions varied between countries because of their income levels and development stages.

Grossman and Krueger's (1991) analysis revealed that income is the most crucial determinant of CO₂ emissions, energy consumption and trade for the Turkish economy. They found two types of relationships between these variables; one type revealed that CO₂ emissions are determined not only by energy consumption and income, but also by trade. The second type of relationship showed that CO₂ emission, energy consumption and foreign trade all play important role in determining Turkey's income level. The importance of foreign trade in determining the level of CO₂ emissions was also emphasised by Andersson, Quigley, and Wilhelmsson (2009).

According to Grossman and Krueger (1991), trade openness affects the environment through three channels: scale, technique and composition effects. The scale effect showed that trade is likely to increase pollution as more outputs and pollutants are produced due to an increase in market access and market activities. However, the technique effect demonstrates that trade openness reduces pollution (Martin & Wheeler, 1992). As technologies advance due to trade liberalisation, obsolete and dirty production processes are replaced by cleaner ones, thereby improving environmental quality (Martin & Wheeler, 1992). Trade openness in developing countries led to specialisation or an increase in pollution-intensive production there.

The recent literature review in Muhammad, Hong, Hoang, Kumar, and Roubaud (2017) suggested that ambiguity among the empirical studies remains. The recent development of a consumption-based CO₂ emissions dataset creates the potential to substantially advance the trade-emissions literature.

Urban populations generate two-thirds of global G.H.G. emissions. Fifty-five percent of the global population resides in urban areas, and this is projected to increase to 66 per cent by 2050. Advancing climate change solutions is a shared responsibility, especially for those living in urban areas. The signatory mayors, governors, prime ministers and other local government leaders collectively committed to provide up to 3.7 gigatons of urban G.H.G. emissions reductions annually by 2030. To achieve this impressive goal, these leaders must assume important new responsibilities. For generations they have led, in relation to CO₂ emissions, an unplanned and unregulated expansion of carbon-focused development (Niu & Lekse, 2017).

The analysis conducted by Hondroyiannis, Sarantis, and Evangelia (2002) established long-run and short-run causality between energy consumption and economic growth. It also has significant policy implications as it has established that certain structural policies in improving economic efficiency lead to energy conservation with no impact on economic growth (Obrovic & Lojanica, 2017).

Soytas and Sari (2009) examined causality and its direction among economic growth, energy consumption and CO₂ emissions. The empirical results of both studies are the same. Neither CO₂ emissions nor energy consumption lead to economic growth, which implies the potential of a CO₂ emissions reduction policy as well as an energy-saving policy without affecting growth. Tsani (2010) also pointed out the unidirectional causality from energy consumption to economic growth. The policy implications of this study are similar to those of the previous study. Ozturk and Acaravci (2010) examined the relation between economic growth and energy consumption in several countries, including

Bulgaria. In Bulgaria there is no long-run relationship between energy consumption and economic growth, indicating the importance a country's economic development as a major determinant of certain energy policies.

On the other hand, Shahbaz, Qazi, Adnan, and Tiwari (2012) examined the relations among energy, CO₂ emissions and economic growth and their results corroborated the premise of long-run causality among variables. These studies raised some new issues, considering environmental control by using energy-efficient technologies (Obradovic & Lojanica, 2017). Redundant energy sources and excessive CO₂ emissions are the main sources of production inefficiency. In addition, Energy, environmental and economic efficiency began to follow an upward path (productivity increased). Technical progress is the key factor for energy efficiency (Obradovic & Lojanica, 2017).

3. Data and model

3.1. Data

The dataset is a panel of 18 Asian countries followed during the years 1980–2014. The list of countries includes: Bahrain, Bangladesh, China, India, Indonesia, Iran, Iraq, Japan, Jordan, Korea, Malaysia, Oman, Pakistan, Philippines, Saudi Arabia, Sri Lanka, Thailand and Vietnam.

In the empirical analysis, CO₂ is the CO₂ emissions (metric tons per capita), G.D.P. (G.D.P. per capita, in constant 2005 U.S. dollars), Energy Consumption (kg of oil equivalent per capita), Urban Population (percent of urban population), Trade ((export + import)/G.D.P.). All variables are obtained from WDI (2015).

3.2. Model

Following other authors, the S.T.I.R.P.A.T. model was used to investigate the relationship between urbanisation and CO₂ emissions (Poumanyong & Kaneko, 2010; Martínez-Zarzoso et al. 2007). The S.T.I.R.P.A.T. model is based on the Influence, Population, Affluence and Technology (I.P.A.T.) model developed by Ehrlich and Holdren (1971). The I.P.A.T. model relates environmental impact to population, affluence (per capita consumption) and technology. The I.P.A.T. identity (Eq.1) is often used as a basis for studying the role of the various factors driving CO₂ emissions (Chertow, 2001):

$$I = P \times A \times T \quad (1)$$

The I.P.A.T. model has been criticised as (1) being primarily a mathematical equation or accounting identity which is not suitable for hypothesis testing and (2) assuming a rigid proportionality between the variables. In response, Dietz and Rosa (1997) proposed a stochastic version of I.P.A.T.

Thus, using this model as a basis, Dietz and Rosa (1997) proposed the S.T.I.R.P.A.T. model as follows. Where α represents the constant term, P, A and T

are the same as that in Eq. (1), b, c and d represent the elasticity of environment impacts with respect to P, A and T, respectively, e_i is the error term and the subscript i denotes the country. 'T' represents an impact, typically measured in terms of the emission level of a pollutant, 'P' denotes population size, 'A' represents a society's affluence and 'T' is a technology index. In order to examine the factors affecting environmental change, the I.P.A.T. model is simple and has its limitations.

$$I_{it} = \alpha_i P_{it}^\beta A_{it} T_{it}^\delta e_{it} \quad (2)$$

The S.T.I.R.P.A.T. model has been applied to analyse the nexus between urbanisation, economic growth, energy consumption and CO₂ emissions (Fan, Liu, Wu, & Wei, 2006; Wang, Zhou, Zhou, & Wang, 2011).

In Eq. (2), countries are denoted by the subscript i ($i = 1, \dots, N$) and the subscript t ($t = 1, \dots, T$) denotes the time period. Country-specific effects included through α_i and e_{it} represent the random error term. Taking natural logarithms of Eq. (2) provides a convenient linear specification for panel estimation. When all variables are in natural logarithms the estimated coefficients can be interpreted as elasticities.

In order to eliminate possible heteroscedasticity, all variables take logarithmic form. Eq. (2) can be written as below:

$$\ln I_{it} = a_i + \beta \ln P_{it} + \gamma \ln A_{it} + \delta \ln T_{it} + \nu_i + e_{it} \quad (3)$$

Where 'P' represents population size, 'A' is measured by the per capita G.D.P., 'T' is a technology index and is measured by the share of the industrial value added in G.D.P. and 't' indicates the year. In order to investigate the impacts of these factors on CO₂ emission, Eq. (3) can be rewritten as follows:

$$\ln CO_{2it} = \alpha_i + \beta \ln P_{it} + \delta \ln PGDP_{it} + \sigma \ln IND_{it} + \nu_i + e_{it} \quad (4)$$

Where CO₂ represents the per capita CO₂ emissions, 'P' is population size, 'PGDP' denotes the level of economic development, 'IND' is the share of value added of the industrial sector in G.D.P. and 'a' and 'e' are the same as in Eq. (2). When it comes to estimating Eq. (4), a distinction is made between models with homogeneous slope coefficients and models with heterogeneous slope coefficients. If the assumption of homogeneous slope coefficients is made, then the model was estimated using standard panel regression techniques. The estimation of panel models with heterogeneous slope coefficients is an active area of econometrics (Eberhardt & Teal, 2011; Eberhardt, Helmers, & Strauss, 2013).

Many studies have shown that population size, economic growth and technological progress are the main driving factors in determining changes in CO₂ emissions.

In order to test whether the evolution of the factors considered in the S.T.I.R.P.A.T. model influences the level of CO₂ emissions over time and across countries, we derived the empirical model taking logarithms of Eq. (4) as follows:

$$\ln CO_{2it} = a_i + \beta \ln GDP_{it} + \delta \ln ENC_{it} + \sigma \ln TR_{it} + \rho \ln URBAN_{it} + \nu_i + \varepsilon_{it} \quad (5)$$

Where the sub-index 'i' refer to countries and 't' refers to the different years. CO₂ is the amount of CO₂ emissions, 'GDP' is the per capita G.D.P., 'ENC' shows the

renewable energy consumption, ‘*TR*’ is the trade (that is the sum of exports and imports divided by G.D.P.) and ‘*URBAN*’ is the urban population.

The coefficients of the explanatory variables are interpreted as elasticities. Time effects are considered as a proxy for all the variables that are common across countries but which vary over time. Within the context, these effects are sometimes interpreted as the effects of emissions-specific technical progress over time.

4. Methodology and the results

4.1. Panel cross-section dependence test

Normalisation of the data is necessary to transform the values to the same unit of measurement, as CO₂ emissions were presented as metric tons while others were presented in US\$. As a result, transformation into a natural log mitigates possible distortions of dynamic properties of the series. It is commonly assumed that disturbances in the panel data models are cross-sectionally independent, especially when the cross-section dimension is large. There is, however, considerable evidence that cross-sectional dependence is often present in panel regression parameters. There is a variety of tests for cross-section dependence in the literature.

Eviews 9 proposes the following tests: Breusch and Pagan (1980) LM, Pesaran (2004) scaled LM, bias-corrected scaled LM, Pesaran (2004) CD. The cross-sectional dependency could be explained in terms of econometrics as individuals forming panels are related to error terms in the panel data model, which is given in Eq. (5). It could be explained that in a situation in which individuals forming a panel are affected by a shock, then other individuals of the panel are affected as well:

$$y_{it} = \alpha_i + \beta_i x_{it} + \varepsilon_{it} \tag{6}$$

$$\text{COV}(\varepsilon_{it}, \varepsilon_{ij}) \neq 0 \tag{7}$$

The CDLM2 test, which is another test to examine cross-sectional dependence, is calculated as below:

$$CD_{LM2} = \sqrt{\frac{1}{N(N-1)}} \left[\sum_{i=1}^{N-1} \sum_{j=i+1}^N TP\hat{\rho}_{ij} \right] \sim N(0,1) \tag{8}$$

In this equation, $\hat{\rho}_{ij}$ shows the estimate of the sum of cross-sectional residuals. The test, which is used when N and T are great ($T \rightarrow \infty$ and $N \rightarrow \infty$), is asymptotically normal distribution. The CD LM test, which is also another test to examining cross-sectional dependence, is calculated with the formula below:

$$CD_{LM} = \sqrt{\frac{2T}{N(N-1)}} \left[\sum_{i=1}^{N-1} \sum_{j=i+1}^N TP\hat{\rho}_{ij} \right] \sim N(0,1) \tag{9}$$

This test is based on the sum of correlation coefficient squares among cross-sectional residuals. This test, which is asymptotically standard normal distribution, is

used when $T > N$ and $N > T$. The null and alternative hypothesis of this test is similar to CD LM1 and CDLM2 tests. Finally, the CDLM1adj test is a modified version of the CDLM1 test, which was developed by Pesaran, Ulla and Yamagata (2008). This test is formulated below.

$$CD_{LM1adj} = \frac{1}{CD_{LM1}} \left[\frac{(T-K)\rho_{ij}^2 \mu T_{ij}}{\sqrt{v_{ij}^2}} \right] \sim N(0,1) \quad (10)$$

CD tests indicate that the series exhibits cross-sectional dependence. Our empirical study begins by examining the cross-sectional dependency across the countries concerned. To investigate the cross-sectional dependence, we performed four different tests (CDBP, CDLM, CD and LM_{adj}) and illustrate the results in Table 2.

The results reported uniformly reject the null hypothesis of cross-section independence, demonstrating the cross-sectional dependence in the data given the statistical significance of the CD statistics. Residuals were tested for cross-sectional dependence using Pesaran's (2004). CD test and stationarity were tested using Pesaran (2007). It is important to test for stationarity in the residuals because residual stationarity is an important part of a good fitting econometric model. Applying the CD test to the regression residuals provides strong evidence of cross-section dependence in each specification.

4.2. Panel unit root tests

Panel unit root tests are similar to unit root tests performed on a single series. The ADF model for panel data may be expressed as:

$$= \rho_i y_{it-1} + \sum_{j=1}^p \delta_i \Delta y_{it-j} + x'_{it} \beta + \varepsilon_{it} \quad (11)$$

Where y_{it} is the series of interest being $i = 1, 2, \dots, N$ cross-section units over periods $t = 1, 2, \dots, T$, x_{it} represents a column vector of exogenous variables including the fixed effects or individual trends, ρ_i is the mean-reversion coefficient, ρ is the lag length of the autoregressive process and it ε_{it} a idiosyncratic disturbance assumed to be a mutually independent. If $\rho_i < 1$, y_{it} is said to be weakly (trend) stationary and if $\rho_i = 1$, then y_{it} presents a unit root. Two natural assumptions may be made about ρ_i in the ADF model for panel data. First, it can assumed that the persistence parameters are common across countries, so that $\rho_i = \rho$ for all i . Using this assumption, and Levin, Lin and Chu (2002) approaches (both testing for a null hypothesis of a unit root against the alternative without unit root) and the Hadri (2000) one (which tests the nullity of unit root against the alternative hypothesis) can be applied. Second, ρ_i is being freely varying across units, allowing for individual unit root processes.

The case of ADF and PP tests was proposed by Maddala and Wu (1999) and Choi (2001) and the IPS test was proposed by Im, Pesaran and Shin (2003). The three of them test the null hypothesis of a unit root against the alternative hypothesis of some individuals without unit roots.

Table 2. Cross-sectional dependence.

| Test | Statistic | Prob |
|-------------------|------------|--------|
| CD _{BP} | 2072.443** | 0.0000 |
| CD _{LM} | 108.6982** | 0.0000 |
| CD | 22.70658** | 0.0000 |
| LM _{adj} | 26.48695** | 0.0000 |

**Indicates significance at the 0.5 level. Source: calculations, authors with Eviews.

Panel unit root tests are reported in Table 3. In any case the nullity of the fact that each variable has a unit root for the series in logs is not rejected. To avoid this misperformance of the unit root tests, we proceed with our panel unit root analysis relaxing the cross-sectional independence assumption, the test proposed by Pesaran (2007).

Not all variables are stationary at 5% significance according to the test results. These tests clearly showed that five of the series are first difference stationary. The results of the tests indicated that time series variables have a unit root. Hence, these results concluded that our panel variables are characterised as I (1) process.

All variables are not static at 5% significance according to the test results. They are static when first differences are taken, I (1). Thus, from all tests, we can conclude that the variables contain a unit root panel. These tests clearly showed that five of the series are first difference stationary.

In every case the null that every variable has a unit root for the series in logs is not rejected. To avoid this misperformance of the unit root tests we proceed with our panel unit root analysis relaxing the cross-sectional independence assumption, the test proposed by Pesaran (2007). These results indicate that variables under analysis integrated order 1.

4.3. Panel cointegration test

In order to ensure broad applicability of any panel cointegration test, it will be important to allow for as much heterogeneity as possible among the individual members of the panel. Therefore, one objective of this paper will be to construct panel cointegration test statistics that allow one to vary the degree of permissible heterogeneity among the members of the panel and in the extreme case pool only the multivariate unit root information, leaving the form of the time series dynamics and the potential cointegrating vectors entirely heterogeneous across individual members (Pedroni, 1997).

Based on the preliminary investigations for these type of estimators in the context of standard cointegrating regressions, the finite sample improvements from these pre-whitening procedures may be particular attractive in the present context of panel cointegration tests with relatively small time series dimensions (Pedroni, 1997).

The panel cointegration test proposed by Pedroni (2004) is reported in Table 4.

4.4. Pooled Mean Group method

To investigate the existence of a long-run equilibrium relationship between CO₂ emissions and the regressors, the study would employ the newly established pooled mean group (P.M.G.) estimator for dynamic heterogeneous panels developed.

Table 3. Panel unit root test.

| | ln CO ₂ | ln GDP | ln GDP ² | ln ENC | ln TR | ln URB |
|-----------------------------|--------------------|------------|---------------------|------------|------------|------------|
| Level 0 | | | | | | |
| Levin, Lin& Chu <i>t</i> * | -1.14002 | 1.45610 | 2.74627 | 1.32314 | 1.06277 | 4.87926 |
| Im, Pesaran and Shin W-stat | 2.73261 | 4.53916 | 5.43837 | 4.19243 | 1.31199 | 2.81241 |
| ADF-Fisher Chi-square | 23.0307 | 34.0323 | 30.7441 | 27.0064 | 33.7236 | 49.5154** |
| PP-Fisher Chi-square | 24.9626 | 8.8628** | 50.7979** | 30.2935 | 33.1112 | 210.778*** |
| Level 1 | | | | | | |
| Levin, Lin& Chu <i>t</i> * | -11.3428** | -7.90280** | -7.40010** | -9.59001 | -6.90320** | 2.42543 |
| Im, Pesaran and Shin W-stat | -12.5700** | -8.09302** | -7.81189** | -10.8238** | -10.7033** | 2.41473 |
| ADF-Fisher Chi-square | 220.089** | 139.321** | 134.942** | 187.113** | 199.013** | 32.1502 |
| PP-Fisher Chi-square | 394.748** | 205.720 | 201.106** | 374.237** | 320.768** | 101.252** |

Critical value is at the 5% level, significance denoted by (**). Source: calculations, authors with Eviews.

Table 4. Pedroni cointegration test results.

| | <i>t</i> statistic | <i>p</i> value | Weighted <i>t</i> statistic | <i>p</i> value |
|---------------------------|--------------------|----------------|-----------------------------|----------------|
| Panel <i>v</i> -statistic | -0.360353 | [0.6407] | -2.562691 | [0.9948] |
| Panel rho-statistic | 0.362038 | [0.6413] | 0.391271 | [0.6522] |
| Panel PP-statistic | -2.467076 | [0.0068] | -6.933851** | [0.0000] |
| Panel ADF-statistic | 0.136593 | [0.5543] | -4.284534** | [0.0000] |
| Group rho-statistic | 1.543711 | [0.9387] | | |
| Group PP-statistic | -10.80500** | [0.0000] | | |
| Group ADF-statistic | -2.664879** | [0.0039] | | |

Critical value is at the 5%, significance level denoted by (**). Source: calculations, authors with Eviews.

The P.M.G. is seen as an intermediate procedure between the mean group (M.G.) estimator and D.F.E. because it involves averaging (representing the M.G. estimator) and pooling (representing the D.F.E.). The P.M.G. estimator allows the short-run coefficients and the error variances to differ across groups, but the long-run coefficients are constrained to be identical (Adusah-Poku, 2016).

Estimation of the long-run relationship between the variables is premised on the existence of a cointegrating relationship between the non-stationary variables. Pesaran and Shin (1999) suggest a (maximum-likelihood) P.M.G. estimator for dynamic heterogeneous panels which fits an A.R.D.L. model to the data. This can further be specified as an error correction equation to enhance economic interpretation. An Error Correction Model (E.C.M.) of an A.R.D.L. (*p*, *q*, *q*... *q*) specification can be considered as shown in Eq. (14) below;

$$\Delta(CO_2)_{it} = \phi(CO_2)_{i,t-1} + \alpha'X_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij}\Delta(CO_2)_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}\Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{12}$$

Where *X* is a vector of explanatory variables; α' contains the long-run dynamics; ϕ is the error correction term and δ_{ij} contains the short-run dynamics (Adusah-Poku, 2016).

The next step is the long-run estimation between CO₂ emissions and other variables in order to estimate the long-run relationship. We must choose the econometric technique best suited to our panel data characteristics. Therefore, we tried to estimate our panel data in the P.M.G. model. The results are shown in Table 5.

Table 5. Long-run estimation results P.M.G. (1, 1, 1, 1, 1).

| Dependent Variable: CO ₂ | | | | |
|-------------------------------------|-------------|-----------|----------|----------|
| Variable | Coefficient | St. Error | T-Ratio | Prob |
| LGDP | 0.19** | 0.050445 | 3.762388 | [0.0002] |
| LENC | 0.49** | 0.069191 | 7.103243 | [0.0000] |
| LTR | 0.02 | 0.016348 | 1.454610 | [0.1464] |
| LURBAN | 1.16** | 0.171171 | 6.768948 | [0.0000] |

The number inside brackets denotes the appropriate lag lengths which chose using Schwarz Criterion. Source: calculations, authors with Eviews.

*Denotes for 5% significance level.

All estimated coefficients are interpreted as long-run elasticities, since the variables are in natural logarithms. We concluded that cointegration is supported by the significantly negative coefficient obtained for the P.M.G. approach. P.M.G. is used to verify the short-run relationship among the variables. The coefficient of variables is statistically significant at the 5% level, indicating that speed of adjustment for short-run to research in the long-run equilibrium is significant. The E.C.M. term is statistically significant and that its magnitude is quite high indicates a faster return to equilibrium in case of disequilibrium. This term shows the speed of adjustment process to restore the equilibrium. The relatively high coefficients imply a faster adjustment process. The values of the coefficients of ECM_{t-1} (-0.26) indicate that the variables will adjust to the long-run equilibrium in about 3.85 period following a short-run shock.

Estimates indicate that a 1% increase in real G.D.P. leads to an increase CO₂ emissions by 0.28%. The energy consumption coefficient, 0.51, suggests 1% energy consumption results in a decrease of about 0.51% in CO₂ emissions. The energy consumption coefficient is positive and significant. The CO₂ emissions elasticity with respect to urbanisation is 0.10, which suggests that a 1% increase in urbanisation will lead to an increase of about 0.8% in CO₂ emissions in the short run in Asian countries. The CO₂ emissions elasticity with respect to urbanisation is positive but insignificant in Iran.

All the coefficients are statistically significant at the 0.05 level, except trade openness in the P.M.G. method. All coefficients have a positive impact on CO₂ emissions. The results indicate a positive and significant relationship between real G.D.P. and CO₂ emissions, suggesting that higher incomes lead to higher emissions.

Our estimated coefficient shows that pollution increases with energy consumption. According to P.M.G. estimates, a 1% increase in energy consumptions increase CO₂ emissions by 0.149%, while a 1% increase in trade openness increases CO₂ emissions by 0.02% in Asian countries. The amount of CO₂ emissions is increasing, because the amount of production and consumption is increasing. However, the rate is decreasing because of the effects of technological change, productivity and energy consumption efficiency. These results are consistent with the results of previous studies in the literature (Wang et al., 2011; Arouri, Ben Youssef, M'Henni, & Rault, 2012; Ozcan, 2013; Farhani, Mrizak, Chaibi, & Rault, 2014). This finding is consistent with Popp (2005), who has investigated the gradual process of the diffusion and adoption of new technologies. It is also consistent with the implications of energy efficiency technologies for climate policy, as discussed by Jaffe, Newell and Stavins et al. (2003).

The results also show that a 1% increase in trade openness increases CO₂ emissions by 0.02%. Finally, the long-run urbanisation elasticity is 1.16. One of the consequences of these results is that omitting the urbanisation variable will have little impact on CO₂ emissions reduction strategies or sustainable development policies. Theories of ecological modernisation and urban environmental transition recognise that urbanisation can have both positive and negative impacts on the natural environment, with the net effect difficult to determine a priori.

Since urbanisation has a statistically significant positive impact on CO₂ emissions, energy and environmental policies are formulated without considering the effects of urbanisation on CO₂ emissions. Asian countries with higher urban populations pollute the environment more than other countries.

4.5. Panel causality analysis

The panel causality test developed was used. This test can be used when N increases and T is constant. Moreover, it can also be used when T > N and when N > T. If the panel data model is considered:

$$y_{it} = \sum_{k=1}^K \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^k \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t} \quad (13)$$

Here, K stands for the lag length. Moreover, the panel for the test is a balanced panel. $\gamma_i^{(k)}$, which is an autoregressive parameter and $\beta_i^{(k)}$ which is the regression coefficient pitch, can change between groups. In addition to these, the tests do not have a random process. This test has a fixed coefficient model. Apart from these, the individual remainders for each cross-sectional unit are independent. This test is based on normal distribution and allows for heterogeneity. In addition, the individual remainders are independently distributed among the groups. The alternative hypothesis of H.N.C. allows for some of the individual vectors (β_i) to be zero. For the Dumitrescu–Hurlin test, the average statistic $W_{N,T}^{H,NC}$, hypothesis can be written as follows:

$$W_{N,T}^{H,NC} = \frac{1}{N} \sum_{i=1}^N W_{i,T} \quad (14)$$

Here, $W_{i,T}$ stands for the individual Wald statistical values for cross-section units.

The panel approach directs cross-sectional dependency across countries in the causality test; therefore, they can lead to misleading conclusions about the nature of causality between variables. The panel Granger causality results reported in Table 6.

The results show panel Granger causality relationships between urbanisation, economic growth and CO₂ emissions at the 5% and 10% significance level. There is a unidirectional causality from CO₂ emissions to urbanisation for Japan, Oman, Pakistan and Sri Lanka. An inverse relationship from urbanisation to CO₂ emissions is found for Bahrain, Bangladesh, Indonesia, Iran, Iraq and Philippines. However, we found that a bidirectional relationship exists for China, Jordan, Korean Republic and Vietnam. Also, there is bidirectional causality from CO₂ emissions to urbanisation for Asian countries. Signs of coefficients for all the countries are positive. Panel Granger

Table 6. Panel Granger causality test.

| | DLnCO ₂ →DLn URB | DLn URB→DLnCO ₂ | DL CO ₂ → DLn GDP | DLn GDP→ DLn Co ₂ |
|--------------|-----------------------------|----------------------------|------------------------------|------------------------------|
| Panel | 2.98475** [0.0308] | 3.94197** [0.0084] | 7.82798** [0.0000] | 2.13577*** [0.0946] |
| Bahrain | 1.05323 [0.4028] | 4.05976** [0.0130] | 1.54868 [0.2231] | 0.96446 [0.4466] |
| Bangladesh | 0.42385 [0.6587] | 5.26140** [0.0115] | 3.08447 [0.0616] | 0.35461 [0.7045] |
| China | 8.61841** [0.0012] | 2.98008*** [0.0671] | 0.45767 [0.6374] | 1.19666 [0.3172] |
| India | 3.99467** [0.0298] | 5.75113** [0.0081] | 0.13444 [0.8748] | 2.02732 [0.1506] |
| Indonesia | 0.52643 [0.4736] | 6.60714** [0.0152] | 0.01401 [0.9065] | 6.10965** [0.0191] |
| Iran | 0.99810 [0.3255] | 11.5571** [0.0019] | 6.20563** [0.0183] | 2.10837 [0.1565] |
| Iraq | 2.63656 [0.1146] | 6.65501** [0.0149] | 2.37323 [0.1336] | 0.03155 [0.8602] |
| Japan | 5.17713** [0.0300] | 0.86190 [0.3604] | 3.76922*** [0.0613] | 8.75230** [0.0059] |
| Jordan | 2.97235** [0.0379] | 2.48327*** [0.0683] | 0.68574 [0.6400] | 0.89147 [0.5063] |
| Korea, Rep | 21.7804** [0.0000] | 5.70006** [0.0232] | 4.00975*** [0.0541] | 5.12858** [0.0307] |
| Malaysia | 0.93135 [0.4059] | 2.20801 [0.1287] | 0.93135 [0.4059] | 2.20801 [0.1287] |
| Oman | 3.70084** [0.0375] | 0.11934 [0.8880] | 0.11001 [0.8962] | 0.38944 [0.6811] |
| Pakistan | 4.58824** [0.0189] | 1.31987 [0.2833] | 1.72903 [0.1959] | 3.37066** [0.0488] |
| Philippines | 0.71256 [0.4991] | 4.84919** [0.0155] | 0.60023 [0.5556] | 2.16669 [0.1334] |
| Saudi Arabia | 1.08312 [0.3061] | 1.85655 [0.1828] | 7.26032** [0.0113] | 0.37820 [0.5431] |
| Sri Lanka | 5.34526** [0.0276] | 1.15077 [0.2917] | 0.34723 [0.5600] | 1.88190 [0.1800] |
| Thailand | 0.66486 [0.4211] | 0.07908 [0.7804] | 2.14920 [0.1527] | 6.41731** [0.0166] |
| Vietnam | 41.8866** [0.0000] | 12.1555** [0.0015] | 45.3079** [0.0000] | 12.5852** [0.0013] |

Note: **, ***The statistical significance at the 5%, 10% levels. Source: calculations, authors with Eviews. Denote X → Y means X Granger causes Y.

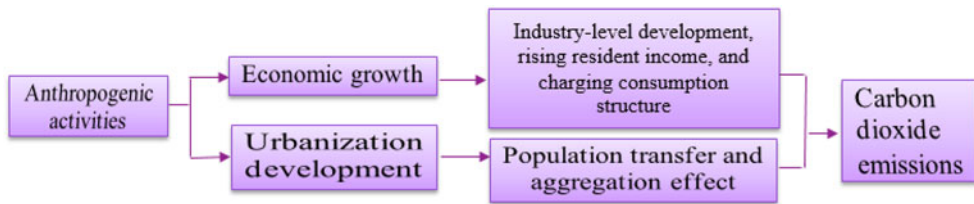


Figure 1. Conceptual framework of factors influencing carbon emissions.

causality tests shows the relationship between economic growth and CO₂ emissions in Asian countries. There is a unidirectional causality from CO₂ emissions to economic growth for Iran and Saudi Arabia. An inverse relationship from economic growth to CO₂ emissions is found for Indonesia, Pakistan and Thailand. However, we found that a bidirectional relationships exist for Japan, Korean Republic and Vietnam. There is a bidirectional between economic growth and CO₂ emissions for Asian countries.

The results also revealed that countries with larger urban populations had more long-run bidirectional relationships than countries with smaller urban populations. Using panel data of countries at different income levels, Fan et al. found that different behaviour patterns can greatly influence environmental change. In other words, the impact of urbanisation on CO₂ emissions varies at different levels of development (Figure 1).

5. Conclusions

This paper investigated the relationship between CO₂ emissions, energy consumption, real income, trade openness and urbanisation in Asian countries during 1980–2014. In the model, population was introduced as a predictor, together with per capita

G.D.P., energy consumption, trade openness and urbanisation. This paper uses the P.M.G. model to explore the impact of urbanisation on CO₂ emissions in Asian countries. The test results suggest a short-run and long-run cointegrated relationship between the five variables. The direction of the long-run causal relationship has also been investigated using the P.M.G. model. The results from the panel E.C.M. indicate that there is bidirectional panel causality between urbanisation and CO₂ emissions and a bidirectional panel causality between G.D.P. and CO₂ emissions.

It is expected that urbanisation will continue to increase in Asian economies and understanding how urbanisation affects CO₂ emissions is an important and timely topic to study. The results show that in Asian countries, elasticity, emissions-urbanisation, is positive. This result has a very important policy implication: once urbanisation reaches a certain level, the effect on emissions turns positive, contributing to reduced environmental damage. Policies to reduce fossil energy consumption and/or CO₂ emissions must go beyond promoting economic growth. This means that economic development itself cannot control CO₂ emissions and/or environmental pollution.

Higher urbanisation is associated with higher economic activity. Higher economic activity generates higher wealth and wealthier residents demand more energy-intensive products (automobiles, air conditioning, etc.) that can increase CO₂ emissions. Affluent residents are also likely to be more environmentally aware. Increased urbanisation also helps to facilitate economies of scale for public infrastructure and these economies of scale result in reduced environmental damage.

The higher energy consumption in the panel of newly industrialised countries gives rise to more CO₂ emissions, which will further pollute our environment. Thus, with respect to economic growth, trade openness and urbanisation, environmental quality is a normal good in the long run.

The governments of Asian countries are trying to reduce energy consumption in urban cities, where transportation is economised by putting more emphasis on the urban transportation network. These types of innovative projects can hinder energy consumption in urban areas and reduce CO₂ emissions in the long cycle of the urbanisation process in these countries. Thus, the low-carbon cities policy package introduces this into the urban corridor through energy efficiency improvement, lowering CO₂ emissions intensity and more control of transport demand in future decades.

The recommendation for Asian countries is to minimise the role of the government in the energy sector in order to increase efficiency. This, of course, implies a reduction of the market share of the current leading companies. Therefore, it is necessary to utilise energy-saving potential, prioritising the implementation of energy efficiency, for both companies and the general population.

It is necessary to use renewable energy sources as an important input for important industrial development. Finally, it should be noted that energy policy objectives are part of the overall objectives of the national economy and should not be considered in isolation, but in conjunction with other social objectives and effects on the economy.

The effects of urbanisation on CO₂ emissions are continuous and change in both the short and long run. In the short run, the urbanisation rate and the shorter

distance between cities contributes to energy conservation and CO₂ emission reductions in local and adjacent regions. In the long run, an uncontrolled increase in urbanisation can hinder CO₂ emissions control. Therefore, we should use both long- and short-run strategies when selecting and implementing low-carbon pathways to urbanisation. In the same way, it is very important to take maximum advantage of scale and agglomeration effects on the reduction of CO₂ emissions in both the short and long run.

The effect of urbanisation on CO₂ emissions are continuous and change in the short and long run. Urbanisation increases resident income, accelerates industrialisation, produces public transit networks or energy-free transport modes and decreases household size, all of which affect CO₂ emissions in various ways. As a result, we have used long- and short- run strategies in the selection and implementation of low-carbon pathways to urbanisation. Similarly, it is very important to make the most of the effects of scale and agglomeration on the reduction of CO₂ emissions in the short and long run.

Promoting urbanisation does not simply mean increasing the urban population. During the urbanisation process, city leaders should maintain the population at optimum levels and cities at reasonable sizes, to ensure the ecological effects are greater than the polluting effects.

Using the new measure of trade openness, we found that low CO₂ emissions are associated with high openness in the long run. In particular, we found that high openness is associated with low CO₂ emissions in the long run, but at a certain level of openness. In other words, there is a turning point towards an openness beyond which greater openness may generate CO₂ high emissions. Policymakers in these countries should also be aware of the consequences if the shift in openness is over.

Therefore, the idea to reduce energy consumption in urban areas is not good decision for policymakers, as it will have a negative impact on future economic performance, unemployment and social issues. For us, technological innovation introduced in the recent urban corridors is the answer to solving the puzzle that still surrounds developing countries such as Malaysian in the past three decades. To this end, most of the research related to CO₂ emissions should focus on urbanisation, energy consumption, trade openness, population and economic growth; as a future direction, researchers should use micro-stage data according to the states or economic regions in Asian countries to compare the effects of consumption, trade openness, population and economic growth on CO₂ emissions.

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