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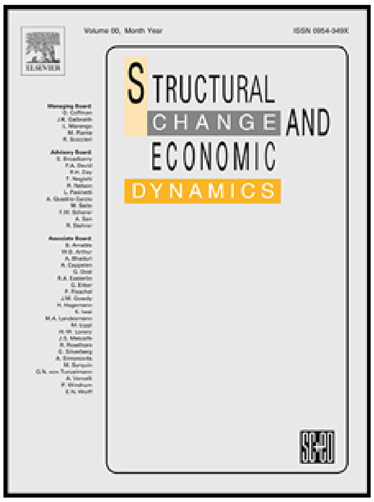

Dynamic linkage among industrialisation, urbanisation, and CO2 emissions in APEC realms: evidence based on DSUR estimation

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Highlights

- Dynamic seemingly unrelated regression (DSUR) is applied for empirical estimation.
- Long run relationship have been revealed among variables in each countries.
- Pairwise Dumitrescu Hurlin panel Causality Test have been used for causal test.

Dynamic linkage among industrialisation, urbanisation, and CO2 emissions in APEC realms: evidence based on DSUR estimation

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Abstract:

This empirical study is a new addition to the existing body of knowledge, which estimates the influence of industrialisation and urbanisation on carbon dioxide emissions in the APEC countries with a new panel estimation technique, the Dynamic Unrelated Seemingly Regression (DSUR). The data covering the years 1990 to 2014 have been used for analysis. Empirical findings of the current study reveal that industrialisation degrades the environment through releasing carbon dioxide to the air. Beside this, it is also observed that the energy intensity, urbanisation, and economic growth enhance the level of environmental pollution via CO_2 emissions. Moreover, unidirectional causality is found between industrialisation and CO_2 emission. For dynamic analysis, a time series analysis is also performed. Finally, policy recommendations regarding R & D are suggested for the industrial and energy sectors.

Keyword; Industrialisation, Urbanisation, Carbon dioxide emissions, Dynamic Unrelated Seemingly Regression, APEC realms

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1. Introduction:

In recent years, identification of the factors liable for excessive carbon dioxide emissions, and which can degrade the environment, has become a hot topic. The data from 2007 to 2012 show that the share of some industries in the world economic structure is continuously growing, but among them the construction sector is the biggest source of carbon dioxide emissions: transport equipment and information technology machinery are also degrading the environment. The growing importance of services and tertiary industries such as producer and consumer services is also increasing the share of CO_2 in their production processes. Although industrialisation greatly increased CO_2 emissions, this rapid urbanisation has also increased carbon dioxide emissions by 74.1%, associated with the aggrandised usage of household utensils. Moreover, as a consequence of rapid urbanisation, more energy is employed to construct urban infrastructure and residential buildings, which further exacerbates the rate of CO_2 emissions in urban areas compared with rural areas (Bo et al., 2018, Zhu et al., 2017).

Through evaluating the structure of household consumption, it can be observed that the demand among the urban population for higher standards of living, especially, food quality, shelter, and entertainment is incessantly increasing, and as a consequence of this, household consumption has tripled during the aforesaid period. Taken together, increasing household consumption combined with the demand for higher standards of living have increased carbon dioxide emissions (Shao et al., 2014). There are several factors which can play critical role to enhance the energy consumption and resultantly increase the carbon dioxide emissions by a country but among them population growth, urbanisation and industrialisation are the most influential and fundamental factors; for example, rapid population growth triggers urbanisation, which generates energy consumption due to the construction of sustainable city infrastructure and residential buildings, while industrialisation can influence the energy consumption by either direct or indirect means. Industrialisation is a process in which new industrial units are installed and previous units are expanded to enhance production to meet market demand, which thus directly enhances the energy consumption profile of a country. Industrial development supports economic growth via cross-sectorial progress that further increases the energy consumption of a country. In addition, industrial development also enhances the opportunities for jobs, therefore engages large numbers of people, hence strengthening their socio-economic status.

Consequently, the strengthened economic status of the populous boosts their demand for luxury items such as: cars, TV sets, refrigerators, computers, *etc.*, which increase energy consumption (Shahbaz and Lean, 2012). The urbanisation and industrialisation triggered by the industrial revolution are the predominant paths for economic and social modernisation, therefore, we can say that the urbanisation and industrialisation increase the consumption of fossil fuel, which consequently emits a considerable amount of carbon dioxide and other greenhouse gases (GHG) (World Bank, 2007). Comparative analysis of the economic data shows that since the 1970s, developing countries have gone through a fast-track process of urbanisation and industrialisation due to the achievements in their economic sector.

The aforementioned developments are always accompanied by an abrupt increase in fossil fuel consumption and carbon dioxide emissions. From 1970 to 2004, corrosive gas emissions have increased from 21 to 38 Gt (accounting for 77% of all anthropogenic greenhouse gas emissions in 2004 (IPCC, 2014). All available evidence supports the sizeable accumulation of CO2 and other GHG due to increased use of fossil fuels as the major driver of global warming, which can potentially cause catastrophic changes in the global climate. Previously, developed countries used to produce most emissions but now due to the employment of the state-of-the-art technologies, these countries have reduced their per capita emissions: however, on the other hand, developing countries due to the lack of state-of-the-art technologies will continue to produce most of the world's emissions while pursuing higher economic growth (Raheem and Ogebe, 2015).

Although, economic growth is not always accompanied by significant greenhouse gas emissions, excluding oil producers, the per capita emissions in high income countries differ by a factor of four, from 7 t of $CO2$ equivalent per capita in Switzerland to 27 t in Australia and Luxembourg (Shahbaz et al., 2014). This highlights that there is no direct correlation among economic development, energy consumption, and carbon dioxide emissions. The history of developed countries suggests that economic development triggers urbanisation and industrialisation, which then stimulates the migration of people from rural areas to urban areas and subsequently shift employment from the agricultural sector to other industrial sectors.

Most studies affirm that urbanisation and industrialisation enhance the energy consumption and $CO2$ emissions (Zhou et al., 2013), whereas, few empirical studies also present a negative correlation among aforementioned factors regarding their influence on $CO2$ emissions. Contemporary studies emphasise that economic development has different effects on energy consumption and $CO2$ emissions during different stages of development, e.g. under different per capita income levels or different rates of urbanisation. The International Energy Agency in 2017 revealed (IEA, 2017) that urbanisation contributed around 70% of energy-related global emissions and this will reach 76% by 2030. The installation of machinery to enhance production and increase economic growth is also harming the environment.

There are many studies which show positive correlation between industrialisation and carbon dioxide emissions. We selected APEC countries for this study due to many reasons. The GDP of APEC countries constitutes approximately 57 % of the global GDP, and it has doubled from 1989 to 2014. Energy demand in the APEC countries has also significantly increased along with GDP by a yearly growth rate of 2.1 %, which is more than the global growth rate of 1.9 %. APEC countries are already responsible for 72 % of global emissions owing to high growth rate and industrialisation (Zafar et al., 2018). It is worth mentioning here that the urban population of APEC economic member countries has reached 1.77 billion in 2014, which is 61% of the total population in the region. According to the World Bank estimates the global urban population will reach 2.38 billion in 2050 (accounting for 77 % of the total population therein), it means urban population of APEC countries will further increase in upcoming years along with the ongoing industrialisation, which will increase environmental damage. Therefore, it is important to study the effect of these variables in APEC countries.

This study contributes to the literature by highlighting the influence of urbanisation and industrialisation on carbon dioxide emissions in APEC countries from 1990-2014. Herein, this is the first study that examines the effect of industrialisation and urbanisation on carbon dioxide emissions in APEC countries. Also, we employed the panel data estimation method of dynamic seemingly unrelated regression (DSUR) that accounts for cross-sectional dependence in the model to produce consistent and reliable results.

The remainder of this paper is structured as follows: in Unit (2) we review the associated literature and former studies that focus on the influence of industrialisation and urbanisation on carbon dioxide emissions. In Unit (3), we explain the data source and variables. In Unit (4) we describe the econometric methods and empirical results. In Unit (5) we present the discussion. In Unit (6) we explain country-by-country long-term analyses, and in Unit (7) we present conclusions and policy recommendations.

2. Literature review

In the previous literature, many scholars have investigated factor behind environmental degradation at local, regional, and global level (Almeida and Carvalho, 2009; Guo et al., 2014; Zhang et al., 2018a, 2018b; Zhang and Zhang, 2018). Several inconclusive studies have projections related to the urbanisation, industrialisation energy intensity, economic growth and, CO_2 emission. Others (Al-Mulali and Ozturk, 2015) determined the elements effecting environmental quality in fourteen Middle-East and North African (MENA) countries from 1996 to 2012. Through use of a fully-modified ordinary least squares (FMOLS) technique, it was revealed that urbanisation, industrialisation, and energy consumption degrade the environment in the long-term, however, the Granger causality showed an enhanced CO2 emission in the short and long-terms, although, other elements displayed dissimilar effects. Keeping in view the outcomes of the study, authors recommended policy-makers take strong measures to protect the environment from degradation.

Al-Mulali et al., (2016) using a dataset from 1980 to 2012 determined the correlation among CO2 emissions, energy consumption, GDP, urbanisation, and trade openness. Their study reported the long and short-term causal relationship among the aforementioned factors and endorsed the effectiveness of the environmental Kuznets curve (EKC) hypothesis. Moreover, the effectiveness of the EKC hypothesis was also authenticated by (Apergis and Ozturk, 2015) using a dataset from 1990 to 2011 and employing a widely used method “moments in Asia”. Asane-Otoo, (2015) found the relationship linking industrialisation, urbanisation, and environmental damage in middle-income states and found that industry harms the environment but urbanisation increases environmental sustainability.

Additionally, (Fan et al., 2015) used the ordinary least square technique (OLS) to examine the influence of urbanisation on the environment: urbanisation enhances the environment in high-income countries. Bekhet and Othman, (2017) found a correlation among urbanisation, energy use, and CO_2 emissions in Malaysia. Meanwhile, they showed that urbanisation has a positive relationship with environmental harm in its preliminary stage and but a negative relationship later in the process. Shahbaz et al., (2016) analysed the effect of urbanisation, energy consumption, and output on CO_2 emissions in Malaysia using quarterly data from 1970Q1 to 2011Q4. The autoregressive distributed lag (ARDL) model revealed the contribution of output on increasing CO_2 emissions. Granger causality demonstrated the long-term link between CO_2 emissions and output; and a unilateral association between urbanisation and CO_2 emissions, however also found a bilateral relationship in the short-term with energy use and CO_2 emissions.

In China, accelerated urbanisation, rapid industrialisation and economic growth have attracted much attention among researchers. At a national level of analysis, (Liu and Bae, 2018) attempted to estimate the influence of energy intensity, urbanisation, and gross domestic product on pollution in China from 1978 to 2006. They observed that the energy intensity, urbanisation, gross domestic product, and industrialisation degrade the environment, for example, economic growth added 38% to the damage to the environment, while a decline in energy intensity played a vital role in maintaining the immunity of China against such environmental degradation and its effects. Wu et al., (2017) recognised the connection between energy intensity, industrialisation, urbanisation, and CO_2 emissions. On the basis of econometric results, policy-makers were asked to make adjustments regarding energy intensity and innovation via advanced technology. Liu and Bae, (2018) observed the connection between energy intensity, industrialisation, urbanisation, and CO_2 emissions in Minhang District, Shanghai. The econometric results demonstrated that energy intensity decreased CO_2 emissions, however urbanisation and industrialisation increased CO_2 emissions, thus, tactical recommendations emphasised decreasing the energy intensity through education about CO_2 emissions and remodelling of the energy structure and industrialisation process.

Li et al., (2012) used data from 1990 to 2010 and examined the effect of urbanisation, industrialisation, economic growth, and technological development on CO_2 emissions from 30 provinces across China through hierarchical classification into five different emission zones. The findings of the study demonstrate that variables regulating CO_2 emissions differ county-wide. In most counties, economic growth and urbanisation displayed more distinct influence on CO_2 emissions compared with other variables. On the other hand, it was also observed that industrialisation is not the main factor causing higher CO_2 emission in high-emission regions.

Therefore, it was suggested that policy-makers adopt diverse strategies to reduce the CO_2 emissions from different CO_2 emission zones. Zhou et al., (2013) found the link between urbanisation, industrialisation, and CO_2 emissions in China through evaluating data from 1995 to 2009. The finding of the analysis recommended that industrial restructuring and technology progress can effectively reduce CO_2 emissions and revealed the positive impact of urbanisation on CO_2 emissions (Wang et al., 2018). Lastly, Ahmed et al. (2019a) examine the effect of urbanisation on CO_2 emissions in Indonesia and find that urbanisation after a threshold level mitigates emissions. Wang et al. (2019) suggest that urbanisation degrades the environment by driving demand for transportation and energy use, while Shaheen et al. (2019) find no effect of urbanisation and industry value added on emissions. Taken together, the aforementioned studies highlight the significance industrialization and urbanisation in influencing CO_2 emissions. It is clear from the above literature that none of the study scrutinized the relationship between urbanisation, industrialisation, and emissions in APEC region. Current study fills this literature gap by examining this relationship using advanced panel data techniques.

3. **Data source and variable description**

Herein, a panel of 18 APEC countries (Australia, Brunei, China, Chile, Hong Kong, Indonesia, Japan, South Korea, Malaysia, Mexico, New Zealand, Peru, Philippines, Russia, Singapore, Thailand, the United States, and Vietnam) are chosen and annual data from 1990 to 2014 selected (carbon dioxide emissions, energy intensity, GDP, industry value added as share of GDP, and urbanisation) from world development indicators, published by the World Bank (WDI). Economic development is assessed using GDP *per capita* (constant 2010 US$), the energy intensity level of primary energy consumption is calculated by (MJ/$2011 PPP GDP), industrialisation is a proxy of the industry value added share of (%GDP), and urbanisation is the proxy variable for urban population (%total). All variables used in present study are modified into natural logarithmic form for purposes of interpretation.

…………………………Insert Table (1) Here………………………..

The variable description is given in Table 1: descriptive statistics are mentioned where different variables are assigned overall values with respect to various countries. The value 5.262% expresses the mean value of dependent variable LOGCO2 and the standard deviation is 0.792% which indicates that the variation is in the range of 4.470% to 6.055%. The calculated range indicates that the variation is lower regarding LOGCO2 whereas the median value is also close to the mean which indicates the centre of data distribution. The minimum value for this variable is 3.592% and maximum value is 7.012%. The first main independent variable of the model LOGIND has mean value 11.069% and standard deviation 0.184%, indicating that the range fluctuates from 10.392% to 11.745%.

The median value is almost same as the mean of this variable which indicates an accurate central point. The minimum value is 9.866% and the maximum is 12.595% for this variable. Our second main independent variable of the model LOGURBAN has an average value of 7.385% and standard deviation 0.746% and a range from 6.639% to 8.131%. These values indicate that the dispersion in the range from the mean value is slightly smaller for this variable in the panel. The median value of 7.354% is similar to the mean indicating an accurate centre of the panel data for this variable. The minimum value is 5.231% and the maximum value is 8.870% for this variable in the panel. Descriptive statistics are summarised in Table 2.

………………….Insert Table (2) Here…………………..

4. Econometric methods and empirical results:

We used a CD test (Pesaran H., 2004) to analyse the cross-sectional independence in our data (Table 4). Based on the associated *P*-values, the alternative of dependent cross-sections was accepted and we rejected the null hypothesis of independent cross-sections for carbon dioxide emissions, energy intensity, GDP, urbanisation, and industry value added. From the outcomes of CD testing, it was concluded that variables under our examination demonstrate cross-sectional dependence, thus, we proceeded with tests robust for determination of cross-sectional dependence.

…..………………Insert Table (3) Here………………………

According to (Ahmed et al., 2019b; Ahmed and Wang, 2019), unit root analysis is imperative to avoid spurious regressions. Therefore, in this study, we have used (Pesaran, 2007) CADF and CIPS unit root tests to discover the integration of characteristics of carbon dioxide emissions, GDP, urbanisation, energy intensity, and industry value added. The CADF and CIPS offer some unique advantages, for example, these tests generate accurate evidence of both cross-sectional dependence and heterogeneity. The results (Table 3) denote that all variables are integrated at their first difference 1(1).

…..…………………Insert Table (4) Here…………………

Few limited studies have used panel co-integration robust tests for determination of cross-sectional dependence. Herein, we applied (Westerlund, 2007) the panel co-integration technique which is reliable for short-term series data about each cross-section and thus produced authentic results in the presence of cross-sectional dependence. The computation, as undertaken by Westerlund, was divided into two group statistics (Gt, Ga) as well as two panel statistics (Pt, Pa). This test is based on the null hypothesis of no co-integration for at least once cross-section for group statistics (Gt, Ga) and all cross-sections for panel statistics (Pt, Pa). The panel tests pool the information from the error correction term, whereas the group statistics do not use such information.

……………………..Insert Table (5) Here………………………

For the long-run analysis, current study used the Dynamic Seemingly Unrelated Cointegrating Regressions (DSUR) technique, which is applicable when time dimension is greater than the cross-sections. We have used the data of 18 APEC countries over the period 1990 to 2014; therefore, cross-sections are less than time dimension. Also, cross-sectional dependence is present in our data, and this methodology is very useful to counter this issue. This method has another advantage that it can be used in case of homogeneous panel as well as in the case of heterogeneous panel.

Dumitrescu and Hurlin, (2012) introduced a causality test which provides reliable results in the absence of cross-sectional independence and is robust against heterogeneity. Since cross-sectional dependence exists in our data, we prefer (Dumitrescu and Hurlin, 2012) causality tests over other causality techniques. This causality test is composed of two different statistics, *i.e.*, Wbar-statistics and Zbar-statistics. The former takes average test statistics, while the latter shows a standard normal distribution. The standardised statistics provided thereby are easy to calculate. These two statistics shows three possibilities, *i.e.*, bi-directional causality, unidirectional causality, and no causality among variables (Zeren and Ari, 2013). Table 6 lists the results of casual relationship tests between the considered variables.

Pair-wise causality analyses express the fact that economic growth Granger causes CO_2 emissions. In this way, industry value added has unidirectional causality running from industry value added to CO_2 emissions. Meanwhile, there exists bidirectional causality between urbanisation and CO_2 emissions. Importantly these both variables Granger cause each other; however the economic growth and industry value added has unidirectional relationship. It means that when economic growth will increase it does not cause industry value added. Bidirectional causality is found between urbanisation and economic growth. Similarly, energy intensity and economic growth Granger cause each other. Urbanisation and industry value added has a mutually bidirectional relationship. Energy intensity and industry value added Granger cause each other (when both variable increase they influence each other). Finally, energy intensity and urbanisation Granger cause each other. The results are summarised in Table 7.

………………………Insert Table (6) Here………………………

5. Discussion:

With the help of a dynamic seemingly unrelated co-integrating regressions (DSUR) model, we have calculated the dynamic analyses associated with carbon dioxide emission, energy intensity, gross domestic product, urbanisation, and industrialisation (share of industrial value added share of GDP) in APEC countries from 1990 to 2014. The urbanisation coefficients, energy intensity, gross domestic product, and industrial values added share are listed (Table 6).

Moreover, the coefficient of GDP with respect to CO_2 emissions is positive and highly significant (at the 1% level). Our results showed that a 1% increase in GDP increased CO_2 emission by 0.508%. Our dynamic result is aligned with (Poumanyvong and Kaneko, 2010, Zhang and Zhao, 2014, Shahbaz et al., 2014b, Xu and Lin, 2015b, Liu and Bae, 2018). One possible reason for this is that increases in *per capita* GDP result in development of industrial sectors, which subsequently increased their carbon dioxide emissions. Industrial sectors consume a large amount of energy, which then increases CO_2 emissions with GDP *per capita* also playing a significant role in increasing the urban population.

Urbanisation induces positive and significant influence on the carbon dioxide emission. In this study, we found that a 1% increase in urbanisation simultaneously increased CO_2 emissions by 0.274%. Although, abrupt increases in urbanisation suggest rapid development in a country, but this comes with increasing CO_2 emissions. When the rural population tends to migrate to urban areas it creates problems related to provision of sanitation, sewage, and drainage services similarly, urbanisation dictates the uneven expansion of city, and therefore increases levels of environmental pollution. Even though urbanisation occurs as a result of economic growth, unexpected urbanisation is a vital issue in APEC countries: first, the increased urban population causes changes in agriculture and manufacturing sectors, increasing the demand for energy, which consequently causes more pollution, second, increased urbanisation facilitates the movement of customers and merchandise, which in return increases the use of vehicles and the associated level of environmental pollution.

Normally, the rise in carbon dioxide emissions is associated with the development of urbanisation, because it influences energy consumption and demand. On the other hand increases in GDP *per capita* improve the lifestyle of the populace, which consequently stimulates rising CO_2 emissions. Herein, we discovered that urbanisation increased CO_2 emissions in APEC countries as did others (York, 2007, Pata, 2018, Xu and Lin, 2015a, Liddle, 2014), albeit (Sharma, 2011) suggests the opposite result in the 69 countries examined in his work.

Next, we investigated the relationship between energy intensity and carbon dioxide emissions. Our results displayed the positive association among energy intensity and carbon dioxide emission, *e.g.* a 1% increase in energy intensity caused a 0.903% increase in carbon dioxide emissions. This is unsurprising because energy is mainly derived from fossil fuels. Previous studies have also reported that energy intensity is a key determinant of CO_2 emissions. In this study, we evaluated the relationship between carbon dioxide emission and industrial development, which demonstrated that both variables exert positive and significant influences on each other.

The industrial sector is a big consumer of energy and emits large amounts of carbon dioxide, thus we discovered that 1% development in the industrial sectors of APEC countries increased their carbon dioxide emissions by 0.208% and consequently harmed the environment. Industry value added is an often-quoted term used to reflect an addition to industrial activities which increases GDP and leads to increased CO_2 emissions (mainly from industrial production). For instance, paper and allied products, petroleum refining, primary metals, and the chemical industry tend to be among the biggest users of energy and emitters of CO_2. As per economic trends, we replace activity as we move from cultivation to industry, and this increase the amount of people in urban areas and also increase industry's added value. Although this trend of upgrading is associated with surges in income and living standards it causes increases in the share of CO_2 emissions in the industrial sector. Our results are aligned with the literature (Liu and Bae, 2018) and (Li and Lin, 2015) also find that industrialisation exerts a significant influence on environmental damage caused in low, middle, and high-income countries (1971 to 2014).

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6. Country-wise long-term analysis:

In the previous section, we discussed the long-term analyses of the panel data, but, to identify the influence of industrialisation and urbanisation on carbon dioxide emission across a specific nation, country-wise long-term analyses are needed. In this section, we describe long-term, single country analyses using time series data.

For the analyses we used a Dynamic Ordinary Least Square (DOLS) model (Table 8). The results demonstrated that the relationship between carbon dioxide emissions and industrial sector development has negative and insignificant impacts on Australia, but in Brunei and Indonesia it has a significant negative effect. Therefore, through the findings of this study, we recommended that aforementioned countries can retain their energy policies regarding the protection of the environment because these policies have been proved to be useful in controlling carbon dioxide emissions in the industrial sector.

In contrast, industrial sector development affected the carbon dioxide emissions from the following countries: China, Chile, Hong Kong, Japan, South Korea, Malaysia, Mexico, New Zealand, Peru, Philippines, Russia, Singapore, Thailand, and Vietnam, however, in the United

States it has a positive, albeit insignificant, effect. On the basis of results of our study, it is proposed that the aforesaid countries should revamp their energy policies and they should encourage their industrialists to install energy-efficient technologies.

Furthermore, positive and significant effects of energy intensity on carbon dioxide emissions are also discovered in: Australia, Brunei, China, Chile, Hong Kong, Indonesia, South Korea, Mexico, New Zealand, Peru, Philippines, Russia, Singapore, Thailand, the United States, and Vietnam. As a consequence, these countries should use renewable energy to reduce their energy intensity. Meanwhile, energy intensity demonstrates negative and significant effects on carbon dioxide emissions in Japan and Malaysia.

GDP growth rate showed a positive and significant influence on carbon dioxide emissions in: Australia, Brunei, China, Chile, Hong Kong, Indonesia, Japan, South Korea, Malaysia, Mexico, New Zealand, Russia, the United States, and Vietnam, hence, these countries should devise such type of policy by which they can reduce their carbon dioxide emissions without decreasing their rate of growth of GDP. On the other hand, our results showed the negative and significant impact of GDP on the carbon dioxide emissions in Peru, the Philippines, Singapore, and Thailand. Therefore, these countries are not required to alter their environmental protection policies because their current policy suffices to control carbon dioxide emissions.

Similarly, the long-term analyses showed negative and significant effects of urbanisation on carbon dioxide emissions in: Brunei, China, Chile, Indonesia, South Korea, Malaysia, New Zealand, Peru, the Philippines, Russia, the United States, and Vietnam. In Australia and Hong Kong there was no significant influence (this analysis excluded Singapore, Thailand, and Mexico).

……………………….Insert Table (8) Here…………………………..

7. Conclusion and policy suggestions

The grave concern of the international community about rising CO_2 levels in the atmosphere paved the way for this study, which can highlight the pros and cons of the policies adopted by APEC countries regarding control of carbon dioxide emissions. To find the main driving factors behind CO_2 emissions, past researchers evaluated the relationship among environmental indicators and different processes, including urbanisation, energy intensity, gross domestic product, and industrialisation (industry value added share of GDP).

For this study, we analysed panel data of APEC countries (1990-2014) using robust, high-efficiency models. Contrary to earlier reports, herein, we employed different analyses such as; CIDF, CIPS panel unit test, the Westerlund panel cointegration test, average correlation coefficient & Pesaran (2004) CD test, dynamic seemingly unrelated co-integrating regressions (DSUR), and a pair-wise Dumitrescu Hurlin panel causality test for evaluating the effect of industrialisation on carbon dioxide emissions by APEC countries. The findings suggest a significant positive impact of both urbanisation and industrialisation on emissions. Economic growth and energy intensity drive CO2 emissions. Industrialisation Granger cause CO2 emissions, while causality between urbanisation and CO2 emissions is bidirectional.

Bidirectional causality exists between GDP and urbanisation and between GDP and industrialisation. Therefore, if APEC countries aim to reduce their CO_2 emissions without adversely affecting their rate of economic growth, then it is imperative for policy-makers to initiate changes at a strategic level in terms of industrial structure and output optimisation. The authorities should introduce new reforms for heavy-and high-emissions industries. In this regard, policymakers should encourage industrial diversity and promote zero-carbon and light industries.

Also, urbanisation degrade the environment but it has bidirectional causality with GDP, which increases the need for planning urban sustainability by improving energy efficiency, employing innovative technology, and encouraging sustainable lifestyle. The APEC countries must implement policies to decrease the price of renewable energy and to discourage fossil fuel usage in industries and household sectors, as renewable energy consumption can reduce emissions (Zhang and Wang, 2019). Policy-makers, must stimulate sustainable, green urbanisation to reduce the risk of environmental degradation; therefore, increasing the influence of renewables on subsequent urbanisation, such as the use of ethanol for motor vehicles, solar lighting, *etc*. The GDP *per capita* significantly influenced CO_2 emissions. Each country aims to increase its GDP *per capita* but development which comes at the cost of environmental degradation is unacceptable, so policy-makers should introduce new technologies, create awareness, and reduce alternative energy options to achieve development targets without increasing CO_2 emissions.

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Variables	Symptoms	Description
Carbon dioxide emissions	CO_2	CO_2 sum of solid of consumption, liquid, gas and fuels consumption
Primary energy	EI	Energy intensity= Energy Consumption kg of oil equivalent /gross domestic product per capita
Urbanisation	URB	Urbanisation = urban population/ total population
Industry value added	IVD	It includes value added in, manufacturing, mining, gas, water and electricity, construction and all input and output.
Economic growth	GDP	Gross domestic product÷total population= gross domestic product per capita

Table No# 1. Variables symptoms and description

Data on all variables are retrieved from World Development indicators (2017)

Table No# 2. Descriptive statistic

Variables	LogCO2	Log EI	LogGDP	Log IND	Log URB
Mean	5.262960	0.714700	11.56616	11.06933	7.385394
Median	5.243793	0.715018	11.39965	10.94819	7.354020
Maximum	7.012497	1.325915	13.20975	12.59520	8.870579
Minimum	3.592068	0.194658	9.981982	9.866118	5.231383
Std. Dev.	0.792503	0.184928	0.728432	0.676633	0.746214

Table 3: Panel Unit Root Test

	CIPS		CADF	
Variables	Level	First Difference	Level	First Difference
$LOGCO_2$	-1.956	-4.252*	-2.630	-3.176*
LOGEI	-2.025	-4.232*	-1.845	-3.024*
LOGGDP	-1.858	-3.197*	-2.121	-2.688*
LOGURB	-1.852	-2.443*	-1.836	-2.443*
LOGIND	-1.725	-3.769*	-1.644	-2.824*

Note: *, ** and *** indicate the statistical significance at 1%, 5% and 10% level, respectively

Table No# 4. Average correlation coefficient & Pesaran (2004) CD test

Variable	CD test	P-value	Corr	Abs (corr)
LogCO2	39.22	0.000	0.634	0.689
Log EI	22.36	0.000	0.362	0.645
LogGDP	58.17	0.000	0.940	0.940
Log URB	47.90	0.000	0.775	0.974
Log IND	37.50	0.000	0.606	0.799

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Table No# 5. Westerlund panel co-integration test

Statistic	Value	Z-value	P-value
Gt	-2.816[a]	-3.452	0.000
Ga	-2.174	4.597	1.000
Pt	-40.307 [a]	-26.401	0.000
Pa	-7.229	-0.647	0.259

Table No# 6. Dynamic seemingly unrelated co-integrating regression (DSUR)

Variable	Co-efficient	Stander. Error	t- value	Probability value
Constant	-5.603306[a]	.1201576	-46.63	0.000
Log EI	.9038875[a]	.0407787	22.17	0.000
Log GDP	.5086645[a]	.0324632	15.67	0.000
Log URB	.2743737[a]	.0169727	16.17	0.000
Log IND	.2087394[a]	.0358649	5.82	0.000
R^2	0.9699[a] (0.0000)			
F-statistic	3581.27[a] (0.0000)			
Countries	18			
Observation	450			

[a] & [b] shows the level of significant of 1%, 5%

Table No# 7. Pairwise Dumitrescu Hurlin panel Causality Test

Hypotheses	W-Stat.	Zbar-Stat.	Prob.
LOGGDP does not homogeneously cause LOGCO2	6.16406	6.50892	8.E-11
LOGCO2 does not homogeneously cause LOGGDP	2.26678	0.02791	0.9777
LOGIND does not homogeneously cause LOGCO2	6.70140	7.40249	1.E-13
LOGCO2 does not homogeneously cause LOGIND	2.42927	0.29812	0.7656
LOGURB does not homogeneously cause LOGCO2	7.36375	8.50396	0.0000
LOGCO2 does not homogeneously cause LOGURB	6.65210	7.32051	2.E-13
LOGEI does not homogeneously cause LOGCO2	4.59807	3.90474	9.E-05

LOGCO2 does not homogeneously cause LOGEI	5.27504	5.03052	5.E-07
LOGIND does not homogeneously cause LOGGDP	2.90931	1.09640	0.2729
LOGGDP does not homogeneously cause LOGIND	4.93263	4.46111	8.E-06
LOGURB does not homogeneously cause LOGGDP	6.47126	7.01978	2.E-12
LOGGDP does not homogeneously cause LOGURB	6.87691	7.69436	1.E-14
LOGEI does not homogeneously cause LOGGDP	3.47387	2.03525	0.0418
LOGGDP does not homogeneously cause LOGEI	6.27094	6.68665	2.E-11
LOGURB does not homogeneously cause LOGIND	5.84925	5.98541	2.E-09
LOGIND does not homogeneously cause LOGURB	5.59479	5.56225	3.E-08
LOGEI does not homogeneously cause LOGIND	4.86889	4.35511	1.E-05
LOGIND does not homogeneously cause LOGEI	5.24832	4.98608	6.E-07
LOGEI does not homogeneously cause LOGURB	7.05182	7.98522	1.E-15
LOGURB does not homogeneously cause LOGEI	7.60299	8.90180	0.0000

Table No# 8. Single country analyses for long run

Country	Variables	Log EI	Log GDP	Log IND	Log URB
Australia	Coefficient	1.245271[a]	1.747836 [a]	-0.559625	-0.448587
	t-statistic	(0.0002)	(0.0000)	(0.2832)	(0.4632)
Brunei	Coefficient	1.807762[b]	11.73928[a]	-1.437257[b]	-4.392663[a]
	t-statistic	(0.0294)	(0.0017)	(0.0547)	(0.0074)
China	Coefficient	1.327789[a]	0.573432[a]	0.774836[a]	-0.682199[a]
	t-statistic	(0.0000)	(0.0047)	(0.0000)	(0.0070)
Chile	Coefficient	0.138576	2.130676[a]	1.299975[c]	-4.715672[a]
	t-statistic	(0.8058)	(0.0070)	(0.0676)	(0.0014)
Hong Kong	Coefficient	0.696486[a]	0.956566[a]	0.008471[c]	-1.211283
	t-statistic	(0.0003)	(0.0005)	(0.0803)	(0.1391)
Indonesia	Coefficient	17.05438[a]	29.74359[a]	-7.243136[b]	-13.24948[b]
	t-statistic	(0.0051)	(0.0061)	(0.0454)	(0.0349)
Japan	Coefficient	-0.216462[b]	0.971468[a]	0.002594[a]	-0.770525[a]
	t-statistic	(0.0502)	(0.0000)	(0.0003)	(0.0006)
Korea, Rep	Coefficient	1.543503[a]	0.692587[b]	0.525570[b]	-1.312969[a]
	t-statistic	(0.0000)	(0.0261)	(0.0337)	(0.0000)
Malaysia	Coefficient	-1.594988[b]	1.411971[b]	0.594409[c]	-2.160051[b]
	t-statistic	(0.0246)	(0.0560	(0.0733)	(0.0205)
Mexico	Coefficient	0.955580[a]	0.591716[b]	0.459498[b]	0.061093
	t-statistic	(0.0000)	(0.0561)	(0.0136)	(0.8006)
New Zealand	Coefficient	1.252985[a]	2.018479[a]	0.616798[b]	-3.604447[a]
	t-statistic	(0.0000)	(0.0004)	(0.0320)	(0.0004)
Peru	Coefficient	0.771353[c]	-0.228005[c]	2.302376[b]	-2.413625[a]

	t-statistic	(0.0633)	(0.7806)	(0.0214)	(0.0000)
Philippines	Coefficient	0.760495[a]	-2.813718[a]	2.347124[a]	-1.409972[c]
	t-statistic	(0.0046)	(0.0052)	(0.0002)	(0.0836)
Russian	Coefficient	0.973397[a]	0.602373[b]	0.238376[c]	-0.600352[a]
Federation	t-statistic	(0.0001)	(0.0172)	(0.0762)	(0.0055)
Singapore	Coefficient	0.506863 [b]	-6.024302[a]	3.151132[c]	7.536475[a]
	t-statistic	(0.2083)	(0.0032)	(0.0678)	(0.0026)
Thailand	Coefficient	1.748763[a]	-2.694035[a]	2.825584[a]	0.509995[b]
	t-statistic	(0.0000)	(0.0000)	(0.0000)	(0.0191)
United States	Coefficient	1.214349[a]	1.306075[a]	0.006739	-0.475095[b]
	t-statistic	(0.0000)	(0.0000)	(0.3575)	(0.0394)
Vietnam	Coefficient	2.351451[a]	4.693531[a]	0.694173[b]	-7.541683[a]
	t-statistic	(0.0004)	(0.0000)	(0.0149)	(0.0000)

[a ,b] ,and [,c] alphabet indicate the 1%, 5% and 10% significance