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Urbanisation and Sustainable Development: Econometric Evidence from Australia

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Abstract

This study examines the effect of urbanisation on economic growth and carbon emissions in Australia for the period 1960-2019 using Cobb-Douglas production function with a Fully Modified Ordinary Least Squares and Dynamic Ordinary Least Squares estimators. The findings indicate that while urbanisation has a significant negative effect on economic growth, it has a significant positive effect on Australia's carbon emissions. Other factors such as physical capital and labour were found to have a significant positive impact on economic growth, while trade openness has a significant negative effect on economic growth. Our findings suggest that energy consumption and foreign direct investment do not affect Australia's economic growth. Further, our results validate the Environmental Kuznets Curve in Australia, while other factors such as energy consumption and population growths were found to worsen carbon emissions. It was also revealed that trade openness and foreign direct investment (FDI) are not insignificant contributors to carbon emissions in Australia. The policy implications are discussed.

Keywords: Australia; Urbanisation; Carbon emissions; Economic growth; Sustainable development

1. Introduction

This paper examines the effect of urbanisation on economic growth and carbon emissions in Australia. Urbanisation is an economic and social modernisation phenomenon (Poumanyvong & Kaneko, 2010). This definition suggests that urbanisation is associated with the movement of people from rural areas to urban areas and a process of structural transformation of rural areas into urban areas (Poumanyvong & Kaneko, 2010). Globally, more people live in urban areas compared to rural areas. For instance, the United Nation (2018) report indicate that 55% the world's population reside in urban areas in 2018; however, 30% of the world's population was urban in 1950. The United Nation (2018) projected that 68% of the world's population would live in urban areas by 2050. The global increase in the number of people in urban areas is not different from Australia's case. Australia remains one of the most urbanised countries in the world. According to United Nations data, in 2015, the percentage of the Australian population living in urban areas was 89.4%; by 90.1% in 2020 and by 2025 is expected to reach 90.6%.

Rapid urbanisation in Australia and across the globe is associated with more resource use and additional pressure on the already fragile ecosystem due to the development of additional urban infrastructure to support the urban areas' unprecedented growth (Poumanyvong & Kaneko, 2010). Thus, changes that occur in urbanisation can affect economic growth and carbon emissions (Sadorsky, 2014). For instance, some scholars argue that urbanisation influence economic growth; however, the argument remains conflicting (Nguyen, 2018). One school of thought argue that urbanisation serves as an engine of economic growth. For instance, Bertinelli and Black (2004) argue that urbanisation generates economic growth. It structures the economy and society by providing opportunities for people to access educational services, employment, and health. Urbanisation also promotes economic growth as it allows countries to have advantages in transaction costs, economies of scale, and internal specialisation (Nguyen, 2018). Furthermore, urbanisation generates positive externalities such as increasing remittance, transfer of technology, skills, which can improve areas where migrant have left (Calì, 2008; Nguyen, 2018; Sasin & McKenzie, 2007). The second strand of the literature argues that urbanisation may have a U-shaped relationship with economic growth (Henderson, 2003; Nguyen, 2018). Thus, at the initial stage of economic development, urbanisation retards economic growth, while at the advanced stage of economic development, urbanisation improves economic growth. It is also argued that urbanisation can impede economic growth if urbanisation if it stresses the existing infrastructure (Alam, Fatima, & Butt, 2007). Lastly, some studies have indicated that urbanisation no effect on economic growth. For instance, Bloom, Canning, and Fink (2008) suggested that urbanisation do not influence economic growth, especially in developing countries.

Besides, urbanisation is argued to influence the environment; however, its impact on carbon emissions is not known in advance. For instance, the Ecological Modernization Theory (EMT) stipulates an inverted U-shaped relationship between urbanisation and carbon emissions. Thus, the EMT argues that environmental problems such as carbon emissions increase as society becomes modernised and seek to address such environmental problems at the later stage of economic development (Poumanyvong & Kaneko, 2010; Sadorsky, 2014). The implication is that at the advanced stage of economic development with efficient technology, urban agglomeration and knowledge spillover effect, societies seek to minimise environmental problems such as mitigating carbon emissions compared to the lower stage of economic development (Gouldson & Murphy, 1997; Mol & Spaargaren, 2000; Poumanyvong & Kaneko, 2010). Like the EMT, the Urban Environmental Transition Theory (UETT) suggests that environmental problems differ across different economic development stages at the city level (McGranahan, 2010). Thus, as cities become prosperous by increasing production, environmental problems also increase; however, as cities become wealthier or at the advanced stage of development, environmental problems reduce as results of improvement in environmental regulation, technological progress, and structural change in the economy (Poumanyvong & Kaneko, 2010; Sadorsky, 2014). Both the EMT and UETT argue that urbanisation can negatively affect urbanisation on the environment, and hence the net impact of urbanisation on carbon emissions is indeterminate (Sadorsky, 2014). The findings of existing empirical remains conflicting. For instance, some studies revealed that urbanisation increases carbon emissions (Poumanyvong & Kaneko, 2010; Wang et al., 2016; Zhang & Lin, 2012; Liu & Bae, 2018). Another strand of the literature indicated that urbanisation reduces carbon emissions (Acheampong, 2019; Adams, Boateng, & Acheampong, 2020; Poumanyvong & Kaneko, 2010; Sadorsky, 2014), while the last strand indicated that an inverted U-shaped relationship exists between urbanisation and carbon emissions (Bekhet and Othman, 2017).

This study's motivation is rooted in the inconsistency in the empirical findings coupled with limited empirical studies that simultaneously examine the effect of urbanisation on economic growth and carbon emissions in Australia. This study, therefore, examines the impact of urbanisation on economic growth and carbon emissions in Australia for the period 1960-2019 using FMOLS and DOLS. Some scholars (Poumanyvong & Kaneko, 2010; Sadorsky,

2014) suggest that investigating the role of urbanisation on economic growth and carbon emissions is critical because if urbanisation is found to increase carbon emissions, this can affect forecasting models and climate change policy in Australia. Thus, earlier forecasting models of Australia's carbon emissions that failed to consider the impact of urbanisation on carbon emissions may generate unreliable information if urbanisation does actually affect carbon dioxide emissions. Policies based on models that omit urbanisation may also be inefficient. Contrarily, if urbanisation is found to mitigate carbon emissions, then modelling the economic and environmental effect of Australia's urbanisation would improve urban planners understanding of the contributing role of urbanisation to sustainable development and help implement sustainable urban policies in the short and long run.

The rest of the paper is outlined as follows: Section 2 presents the methodology and data, while Section 3 presents the empirical results. Section 4 presents the conclusions and policy implications.

2. Methodology and Data

2.1 Empirical model for economic growth

This study uses Cobb-Douglas production function framework to examine the effect of urbanisation on Australia's economic growth. Following existing studies such as Omri and Kahouli (2014) and Shahbaz, Khan, and Tahir (2013), economic growth is specified in equation (1) as a function of capital (K), labour (LAB), energy consumption, (ENER) urbanisation (URBP), trade openness (TRAD) and foreign direct investment (FDI). The subscript t refers to time.

$$GDPC_t = f(K_t, LAB_t, ENER_t, URBP_t, TRAD_t, FDI_t) \quad (1)$$

For empirical estimation, the reduced-form of the log-linear empirical model for the estimation is given as:

$$lnGDPC_t = \theta_0 + \theta_1 lnK_t + \theta_2 lnLAB_t + \theta_3 lnENER_t + \theta_4 lnURBP_t + \theta_5 lnTRAD_t + \theta_6 lnFDI_t + \mu_t \quad (2)$$

From equation (2), $lnGDPC_t$ denotes the log of economic growth respectively. lnK_t indicates the log of physical capital, $lnLAB_t$ represents the log of labour, $lnENER_t$ represents the log of energy consumption, $lnURBP_t$ denotes urbanisation, $lnTRAD_t$ represents the log of trade openness and $lnFDI_t$ denotes the log of foreign direct investment. The term μ_t is the error term, which is assumed to be normally distributed, and the subscript *t* refers to time. In this study, we expect physical capital and labour to have a positive effect on economic growth and hence $\theta_1 > 0$ and $\theta_2 > 0$ (Omri, 2013; Solow, 1956). Also, we expect the relationship between energy consumption and economic growth to be positive and hence $\theta_3 > 0$ (Nasreen & Anwar, 2014; Omri, 2013, 2014). We hypotheses that urbanisation has a positive effect on economic growth and hence $\theta_4 > 0$ (Henderson, 2003; Nguyen, 2018). We also expect trade openness and foreign direct investment to increase economic growth and hence $\theta_5 > 0$ and $\theta_6 > 0$ (Brueckner & Lederman, 2015; Pandya & Sisombat, 2017; Sakyi, Villaverde, Maza, & Bonuedi, 2017).

2.2 Empirical model for carbon emissions

Following Shahbaz, Bhattacharya, and Ahmed (2017), we state that carbon emission is a function of economic growth, population, urbanisation, trade openness and foreign direct investment. Therefore, the carbon emissions function is as indicated in equation (3):

$$CO2kt_t = f(GDPC_t, POPG_t, ENER_t, URBP_t, TRAD_t, FDI_t) \quad (3)$$

Where GDPC represents economic growth, POPG represents population growth and other variables remained as defined above. For empirical estimation, the log-linear form of the empirical equation is specified in Eq. (3). Following the argument on the Environmental Kuznets curve (EKC) hypothesis (Acheampong, 2019; Stern, 2004; Stern & Common, 2001), we also augment equation (1) with the squared of economic growth. The EKC hypothesis suggests that there an inverted U-shaped relationship between economic growth and environment. Thus, at the initial stage of economic development, environmental degradation and pollution increase but after a certain threshold of economic development, environmental quality improves (Grossman and Krueger, 1995). Analysing the impact of urbanisation on carbon emissions within the framework of the EKC is important since at the advanced stage of countries' economic development, urbanisation could spur technological development, which is critical for addressing carbon emissions (Poumanyvong & Kaneko, 2010).

$$lnCO2kt_t = \alpha_1 + \beta_1 lnGDPC_t + \beta_2 lnGDPC^2{}_t + \beta_3 lnPOPG_t + \beta_4 lnENER_t + \beta_5 lnURBP_t + \beta_6 lnTRAD_t + \beta_7 lnFDI_t + \varepsilon_t \quad (4)$$

In equation (4), $lnCO2kt_t$ indicates the log of carbon emissions. $lnGDPC_t$ and $lnGDPC^2{}_t$ denote the log of the main term and squared term of economic growth, respectively. $POPG_t$

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indicates population growth, $lnENER_t$ represents the log of energy consumption, $lnURBP_t$ denotes urbanisation, $lnTRAD_t$ represents the log of trade openness and $lnFDI_t$ denotes the log of foreign direct investment. The term ε_t is the error term, which is assumed to be normally distributed. If the EKC is valid, then $\beta_1 < 0$ and $\beta_2 > 0$, otherwise $\beta_1 > 0$ and $\beta_2 < 0$ (Acheampong, 2019; Acheampong, Amponsah, & Boateng, 2020; Shahbaz, Nasir, & Roubaud, 2018). We also expect the population to increase carbon emissions and hence $\beta_3 > 0$. Energy consumption is expected to increase carbon emissions and hence $\beta_4 > 0$ (Sadorsky, 2014). We hypothesis that urbanisation mitigates carbon emissions and hence $\beta_5 < 0$ (Poumanyvong & Kaneko, 2010). We also expect that trade openness and foreign direct investment reduce carbon emissions and hence $\beta_6 < 0$ and $\beta_1 < 0$ (Antweiler, Copeland, & Taylor, 2001; Doytch & Uctum, 2016).

2.3 Estimation strategies

Given that this study examines the long-run effect of urbanisation on economic growth and urbanisation, we follow Mahjabeen et al. (2020) and Sarkodie and Strezov (2018) to estimate the above equations using the Pedroni (2001a; 2001b) Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS). Unlike the conventional econometric technique such Ordinary Least Squares, applying FMOLS in this study is essential since it addresses econometrics issues such as serial correlation and endogeneity among the regressors (Bhattacharya, Awaworyi Churchill, & Paramati, 2017). Pedroni (2001a) also argued that the FMOLS provides consistent estimates of the cointegrating vector's sample mean in the presence of heterogeneity in the cointegration relationship. Like the FMOLS, the Pedroni (2001b) DOLS controls for endogeneity, serial correlation and generates unbiased estimates. Both FMOLS and DOLS are employed to estimate the long-run output and carbon emissions elasticities.

2.4 Data

This study uses a annual time series dataset for the period 1960-2019. The data on economic growth is measured using GDP per capita (constant 2010 US$), carbon emissions measured CO2 emissions (kt), energy consumption measured in kg of oil equivalent per capita, urbanisation measured in urban population as % of the total population, physical capital measured in gross fixed capital formation (constant 2010 US$), labour measured in the total labour force, population growth measured in annual percentage of population growth, trade openness measured trade as a percentage of GDP and foreign direct investment measured FDI

Net Inflows (% of GDP). These variables were obtained from the World Development Indicators (WDI) database. The variables were transformed into their natural logarithm, except population growth.

Table 1: Descriptive statistics for the variables used in the model

	lnco2kt	lngdpc	lngdpc2	popg	lnfdi	lntrad	lnurbp	lnener	lngfc	lnlab
Mean	12.354	10.467	109.671	1.531	0.698	3.518	4.439	8.455	25.507	16.170
Median	12.473	10.466	109.543	1.480	0.939	3.485	4.442	8.475	25.460	16.157
Maximum	12.886	10.954	119.992	3.380	1.947	3.824	4.456	8.694	26.635	16.418
Minimum	11.387	9.865	97.319	0.625	-1.552	3.211	4.401	8.027	24.204	15.955
Std. Dev.	0.436	0.329	6.875	0.454	0.752	0.192	0.012	0.184	0.736	0.148
Skewness	-0.664	-0.129	-0.089	1.363	-1.115	-0.005	-1.267	-0.796	0.040	0.099
Kurtosis	2.349	1.882	1.855	6.317	4.281	1.530	4.229	2.653	1.837	1.657
Jarque-Bera	5.201	3.293	3.359	45.327	13.498	5.400	19.830	6.190	3.395	2.303
Probability	0.074	0.193	0.186	0.000	0.001	0.067	0.000	0.045	0.183	0.316

where lnco2kt represents carbon emissions, lngdpc represents economic growth, lngdpc2 represents economic growth squared, popg represent population, lnfdi represents foreign direct investment, lntrade represents trade openness. lnurbp represents urbanisation, lnener represents energy consumption; lngfc represents physical capital and lnlab represents labour

Table 1 presents the descriptive statistics for the variables. From the descriptive statistics, carbon emissions have a negative mean of 12.354%. Economic growth and population growth have a mean of 10.467% and 1.531%, respectively. Energy consumption has a mean of 8.455%, and urbanisation has a mean of 4.439%. Physical capital and labour have a mean of 25.507% and 16.170%, respectively. Trade openness and foreign direct investment have a mean of 3.518% and 0.698%, respectively. The Jarque-Bera statistics indicate that foreign direct investment, trade openness, energy consumption, urbanisation and population growth are not normally distributed, while physical capital, labour economic growth are normally distributed.

3. Empirical results

3.1 Unit root test

Table 2 displays the results of the unit root test. We check the stationarity properties of the variables using the Augmented Dickey-Fuller (ADF) (Dickey & Fuller, 1979) and Philips-Perron (PP) (Phillips & Perron, 1988) tests before estimating the empirical models. The results from the ADF and PP indicate that economic growth, economic growth squared, physical capital, labour, trade openness, population growth and urbanisation are non-stationary at levels.

At the same time, carbon emissions, energy consumption and foreign direct investment are stationary at levels. At first difference, ADF and PP suggest that all the variables are stationary.

Table 2: Stationarity tests of the variables used in estimation

	Levels		**1st difference**	
Variables	**ADF**	**PP**	**ADF**	**PP**
Lnco2kt	-4.074***	-6.044***	-6.451***	-6.541***
lnener	-3.114**	-3.449**	-7.760***	-7.798***
lnfdi	-4.246***	-4.461***	-11.832***	-16.499***
lngdpc	-1.667	-1.599	-6.338***	-6.330***
lngdpc2	-1.434	-1.375	-6.385***	-6.360***
lngfc	-1.273	-1.247	-6.203***	-6.115***
lnlab	1.724	1.524	-3.993***	-3.941***
lntrad	-0.622	-0.245	-8.387***	-8.973***
Popg	-2.438	-4.882***	-9.914***	-13.379***
lnurbp	-1.152	-3.267**	-2.787*	-2.783*

$p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; where lnco2kt represents carbon emissions, lngdpc represents economic growth, lngdpc2 represents economic growth squared, popg represent population, lnfdi represents foreign direct investment, lntrade represents trade openness. lnurbp represents urbanisation, lnener represents energy consumption; lngfc represents physical capital and lnlab represents labour

3.2 Long-run estimates for economic growth

Table 3 presents the FMOLS and DOLS results for the economic growth. The results from both FMOLS and DOLS estimators suggest that urbanisation has a significant negative effect (-6.0546 (FMOLS) and -5.519 (DOLS)) on economic growth. This result implies that urbanisation is detrimental to Australia's economic growth. This result can be explained using Lipton (1977) urban bias theory. The urban bias theory argues that over-concentration of scarce resources in the urban sector at the expense of rural areas keeps urban areas that already have a larger share of the national income better off, with rural areas descending into an increasing worsening income inequality (Lipton, 1977). The inequality between the urban and rural areas hampers economic growth. Similarly, Weede (1987) argues that countries with large income inequality between urban and rural areas suffer from urban bias and found that urban bias retards economic growth.

Table 3: FMOLS and DOLS results for Economic Growth

Variable	Coefficient	Std. Error	t-Statistic	P-value	Coefficient	Std. Error	t-Statistic	P-value
	FMOLS				**DOLS**			
lngfc	0.202***	0.043	4.660	0.000	0.191***	0.047	4.057	0.001
lnlab	0.664***	0.144	4.615	0.000	0.676***	0.152	4.436	0.000
lntrad	-0.088*	0.048	-1.849	0.083	-0.079	0.059	-1.356	0.192
lnfdi	0.000	0.004	0.044	0.966	0.001	0.005	0.183	0.857
lnener	-0.008	0.079	-0.097	0.924	0.026	0.096	0.271	0.789
lnurbp	-6.046***	0.694	-8.708	0.000	-5.519***	0.792	-6.966	0.000
Constant	21.990	2.870	7.663	0.000	19.412	3.462	5.607	0.000
R^2	0.997				0.998			
Adj R^2	0.996				0.997			

$p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. where lngfc represents physical capital, lnlab represents labour, lntrade represents trade openness, lnfdi represents foreign direct investment, lnener represents energy consumption and lnurbp represents urbanisation.

This result contradicts the findings of (Bertinelli & Black, 2004; Henderson, 2003; Nguyen, 2018), which revealed that urbanisation promotes economic growth. The results further indicate that physical capital and labour have a significant positive impact on economic growth, whiles trade openness has a significant negative impact on economic growth. It is observed that energy consumption and foreign direct investment have no statistically significant impact on economic growth.

3.3 Long-run estimates for carbon emissions

Table 4 displays the FMOLS and DOLS estimates for carbon emissions. The results from both FMOLS and DOLS estimators suggest that urbanisation has a significant positive effect on carbon emissions. This result indicates that urbanisation is an important contributor to carbon emissions. Urbanisation in generating carbon emissions in Australia implies that urbanisation results in traffic congestions and overcrowding, consequently increasing energy consumption and carbon emissions (Breheny, 2001; Poumanyvong & Kaneko, 2010; Rudlin & Falk, 1999). This finding is consistent with the results of Wang et al. (2016), Zhang and Lin (2012) and Wu, Shen, Zhang, Skitmore, and Lu (2016), which revealed that urbanisation contributes to higher carbon emissions. The results also indicate that the main term of economic growth and its squared term has a significant positive and negative effect on carbon emissions. This validates the environmental Kuznets curve in Australia, and hence economic growth will improve carbon emissions in the long term. This result is consistent with the findings (see Ahmad et al., 2017;

Apergis & Ozturk, 2015; Apergis & Payne, 2009, 2010; Ben Jebli, Ben Youssef, & Ozturk, 2016).

Table 4: FMOLS and DOLS results for Carbon Emissions

Variable	Coefficient	Std. Error	t-Statistic	P-value	Coefficient	Std. Error	t-Statistic	P-value
	FMOLS				**DOLS**			
lngdpc	19.705***	2.835	6.950	0.000	19.830***	3.531	5.616	0.000
lngdpc2	-0.899***	0.132	-6.824	0.000	-0.903***	0.164	-5.503	0.000
lnener	0.808***	0.156	5.192	0.000	0.735***	0.195	3.766	0.001
popg	0.031**	0.011	2.698	0.011	0.025*	0.014	1.738	0.091
lnfdi	-0.007	0.007	-0.952	0.348	-0.007	0.009	-0.805	0.426
lntrad	0.119	0.095	1.249	0.220	0.091	0.120	0.763	0.450
inurbp	5.261***	0.710	7.405	0.000	5.372***	0.856	6.277	0.000
Constant	-125.957	14.643	-8.602	0.000	-126.648	17.874	-7.086	0.000
R^2	0.992				0.993			
Adj R^2	0.990				0.992			

$p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. where lngdpc represents economic growth, lngdpc2 represents economic growth squared, lnener represents energy consumption, popg represent population, lnfdi represents foreign direct investment, lntrade represents trade openness and lnurbp represents urbanisation,

Other factors such as energy consumption and population growths have a significant positive effect on carbon emissions. A unit increase in energy consumption will result in about 75 to 81 units of increase carbon dioxide (based on the DOLS and FMOLS estimates, respectively). Thus, a consistent increase in population and excessive use of energy would increase Australia's carbon emissions. Our results are in line with the results of Dzator and Acheampong (2020) and Shahbaz et al. (2017), which indicated that population and energy consumption are major contributors to carbon emissions. The results suggest that trade openness and FDI have insignificant effects on carbon emissions. Still, this finding contradicts Shahbaz et al. (2017) findings which argue that globalisation plays a significant role in mitigating carbon emissions in Australia.

4. Conclusion and policy implications

This study examines the effect of urbanisation on economic growth and carbon emissions in Australia for the period 1960-2019 using FMOLS and DOLS. The findings indicate that while urbanisation has a significant negative effect on economic growth, it has a significant positive effect on Australia's carbon emissions. Other factors such as physical capital and labour were found to have a significant positive impact on economic growth, while trade openness has a significant negative effect on economic growth. Our findings suggest that energy consumption and foreign direct investment do not affect Australia's economic growth. Further, our results validate the environmental Kuznets curve in Australia. Thus, at the initial stage of economic development, environmental degradation and pollution increase but after a certain threshold of economic development, environmental quality improves (Grossman and Krueger, 1995). Therefore, given the advanced stage of Australia's economic development, its economic growth contributes to carbon emissions mitigation. Our findings suggest that other factors such as energy consumption and population growths worsen carbon emissions. It was also revealed that trade openness and FDI are not insignificant contributors to carbon emissions in Australia.

These results have important policy implications for decarbonising Australia's economy while achieving robust economic growth. Our results that urbanisation reduces economic growth while increasing carbon emissions suggest that Australia's urbanisation is unsustainable. This indicates that Australia's rapid urbanisation will be associated with excess use of resources such as energy due to the expansion of urban infrastructure facilities. Therefore, to decarbonise the economy, urban planners must develop energy-efficient and sustainable urban infrastructure systems to improve their efficient use of energy. Another implication of the study is that drastic policies must be implemented to reduce the ever-increasing population in urban areas across the countries. Our findings indicate that economic growth would contribute to carbon emissions mitigating. This requires improving energy efficiency, transitioning towards renewable energy, and implementing policies to maintain population growth in Australia.

Conflict of interest

The authors declare no conflict of interest.

Reference

Acheampong, A. O. (2019). Modelling for insight: Does financial development improve environmental quality? *Energy Economics*, *83*, 156-179. doi:https://doi.org/10.1016/j.eneco.2019.06.025
Acheampong, A. O., Amponsah, M., & Boateng, E. (2020). Does financial development mitigate carbon emissions? Evidence from heterogeneous financial economies. *Energy Economics*, *88*, 104768. doi:https://doi.org/10.1016/j.eneco.2020.104768
Adams, S., Boateng, E., & Acheampong, A. O. (2020). Transport energy consumption and environmental quality: Does urbanisation matter? *Science of The Total Environment*, *744*, 140617. doi:https://doi.org/10.1016/j.scitotenv.2020.140617
Ahmad, N., Du, L., Lu, J., Wang, J., Li, H.-Z., & Hashmi, M. Z. (2017). Modelling the CO 2 emissions and economic growth in Croatia: Is there any environmental Kuznets curve? *Energy*, *123*, 164-172. doi:10.1016/j.energy.2016.12.106
Alam, S., Fatima, A., & Butt, M. S. (2007). Sustainable development in Pakistan in the context of energy consumption demand and environmental degradation. *Journal of Asian Economics*, *18*(5), 825-837.
Antweiler, W., Copeland, B. R., & Taylor, M. S. (2001). Is Free Trade Good for the Environment? *The American economic review*, *91*(4), 877-908. Retrieved from http://www.jstor.org/stable/2677817
Apergis, N., & Ozturk, I. (2015). Testing Environmental Kuznets Curve hypothesis in Asian countries. *Ecological Indicators*, *52*(Supplement C), 16-22. doi:https://doi.org/10.1016/j.ecolind.2014.11.026
Apergis, N., & Payne, J. E. (2009). CO2 emissions, energy usage, and output in Central America. *Energy Policy*, *37*(8), 3282-3286. doi:https://doi.org/10.1016/j.enpol.2009.03.048
Apergis, N., & Payne, J. E. (2010). The emissions, energy consumption, and growth nexus: Evidence from the commonwealth of independent states. *Energy Policy*, *38*(1), 650-655. doi:https://doi.org/10.1016/j.enpol.2009.08.029
Bekhet, H. A., & Othman, N. S. (2017). Impact of urbanisation growth on Malaysia CO2 emissions: Evidence from the dynamic relationship. *Journal of Cleaner Production*, *154*, 374-388. doi:https://doi.org/10.1016/j.jclepro.2017.03.174
Ben Jebli, M., Ben Youssef, S., & Ozturk, I. (2016). Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. *Ecological Indicators*, *60*, 824-831. doi:https://doi.org/10.1016/j.ecolind.2015.08.031
Bertinelli, L., & Black, D. (2004). Urbanisation and growth. *Journal of Urban Economics*, *56*(1), 80-96.
Bhattacharya, M., Awaworyi Churchill, S., & Paramati, S. R. (2017). The dynamic impact of renewable energy and institutions on economic output and CO2 emissions across regions. *Renewable Energy*, *111*, 157-167. doi:https://doi.org/10.1016/j.renene.2017.03.102
Bloom, D. E., Canning, D., & Fink, G. (2008). Urbanisation and the wealth of nations. *Science*, *319*(5864), 772-775.
Breheny, M. (2001). Densities and sustainable cities: the UK experience. *Cities for the new millennium*, 39-51.
Brueckner, M., & Lederman, D. (2015). Trade openness and economic growth: Panel data evidence from Sub-Saharan Africa. *economica*, *82*, 1302-1323.
Calì, M. (2008). Urbanisation, inequality and economic growth: Evidence from Indian states and towns. *background note for the World Development Report, London: Overseas Development Institute*.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series With a Unit Root. *Journal of the American Statistical Association, 74*(366), 427-431. doi:10.2307/2286348

Doytch, N., & Uctum, M. (2016). Globalisation and the environmental impact of sectoral FDI. *Economic Systems, 40*(4), 582-594. doi:https://doi.org/10.1016/j.ecosys.2016.02.005

Dzator, J., & Acheampong, A. O. (2020). The Impact of Energy Innovation on Carbon Emission Mitigation: An Empirical Evidence from OECD Countries. In C. M. Hussain (Ed.), *Handbook of Environmental Materials Management* (pp. 1-19). Cham: Springer International Publishing.

Gouldson, A., & Murphy, J. (1997). Ecological modernisation: economic restructuring and the environment. *The Political Quarterly, 68*(5), 74-86.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. The Quarterly Journal of Economics, 110(2), 353-377. doi:10.2307/2118443

Henderson, V. (2003). The urbanisation process and economic growth: The so-what question. *Journal of Economic Growth, 8*(1), 47-71.

Lipton, M. (1977). *Why poor people stay poor: a study of urban bias in world development*: Temple Smith; Australian National University Press.

Liu, X., & Bae, J. (2018). Urbanisation and industrialisation impact of CO2 emissions in China. *Journal of Cleaner Production, 172*, 178-186. doi:https://doi.org/10.1016/j.jclepro.2017.10.156

Mahjabeen, Shah, S. Z. A., Chughtai, S., & Simonetti, B. (2020). Renewable energy, institutional stability, environment and economic growth nexus of D-8 countries. Energy Strategy Reviews, 29, 100484. doi:https://doi.org/10.1016/j.esr.2020.100484

McGranahan, G. (2010). *The citizens at risk: from urban sanitation to sustainable cities*: Earthscan.

Mol, A. P. J., & Spaargaren, G. (2000). Ecological modernisation theory in debate: A review. *Environmental Politics, 9*(1), 17-49. doi:10.1080/09644010008414511

Nasreen, S., & Anwar, S. (2014). Causal relationship between trade openness, economic growth and energy consumption: A panel data analysis of Asian countries. *Energy Policy, 69*, 82-91. doi:10.1016/j.enpol.2014.02.009

Nguyen, H. M. (2018). The relationship between urbanisation and economic growth: An empirical study on ASEAN countries. *International Journal of Social Economics*.

Omri, A. (2013). CO2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. *Energy Economics, 40*, 657-664. doi:10.1016/j.eneco.2013.09.003

Omri, A. (2014). An international literature survey on energy-economic growth nexus: Evidence from country-specific studies. *Renewable and Sustainable Energy Reviews, 38*(Supplement C), 951-959. doi:https://doi.org/10.1016/j.rser.2014.07.084

Omri, A., & Kahouli, B. (2014). Causal relationships between energy consumption, foreign direct investment and economic growth: Fresh evidence from dynamic simultaneous-equations models. *Energy Policy, 67*, 913-922. doi:https://doi.org/10.1016/j.enpol.2013.11.067

Pandya, V., & Sisombat, S. (2017). Impacts of foreign direct investment on economic growth: empirical evidence from Australian economy. *International Journal of Economics and Finance, 9*(5), 121-131.

Pedroni, P. (2001a). Fully modified OLS for heterogeneous cointegrated panels. In *Non-stationary panels, panel cointegration, and dynamic panels*: Emerald Group Publishing Limited.

Pedroni, P. (2001b). Purchasing power parity tests in cointegrated panels. *Review of Economics and Statistics, 83*(4), 727-731.

Phillips, P. C., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika, 75*(2), 335-346.
Poumanyvong, P., & Kaneko, S. (2010). Does urbanisation lead to less energy use and lower CO2 emissions? A cross-country analysis. *Ecological Economics, 70*(2), 434-444. doi:10.1016/j.ecolecon.2010.09.029
Rudlin, D., & Falk, N. (1999). *Building the 21st century home: the sustainable urban neighbourhood*: Butterworth-Heinemann.
Sarkodie, S. A., & Strezov, V. (2018). Assessment of contribution of Australia's energy production to CO2 emissions and environmental degradation using statistical dynamic approach. Science of The Total Environment, 639, 888-899. doi:https://doi.org/10.1016/j.scitotenv.2018.05.204
Sadorsky, P. (2014). The effect of urbanisation on CO2 emissions in emerging economies. *Energy Economics, 41*, 147-153. doi:https://doi.org/10.1016/j.eneco.2013.11.007
Sakyi, D., Villaverde, J., Maza, A., & Bonuedi, I. (2017). The effects of trade and trade facilitation on economic growth in Africa. *African Development Review, 29*(2), 350-361.
Sasin, M. J., & McKenzie, D. (2007). Migration, remittances, poverty, and human capital: conceptual and empirical challenges.
Shahbaz, M., Bhattacharya, M., & Ahmed, K. (2017). CO2 emissions in Australia: economic and non-economic drivers in the long-run. *Applied Economics, 49*(13), 1273-1286.
Shahbaz, M., Khan, S., & Tahir, M. I. (2013). The dynamic links between energy consumption, economic growth, financial development and trade in China: Fresh evidence from multivariate framework analysis. *Energy Economics, 40*, 8-21. doi:https://doi.org/10.1016/j.eneco.2013.06.006
Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental degradation in France: The effects of FDI, financial development, and energy innovations. *Energy Economics, 74*, 843-857. doi:https://doi.org/10.1016/j.eneco.2018.07.020
Solow, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics,, 70*(1), 65-94.
Stern, D. I. (2004). The Rise and Fall of the Environmental Kuznets Curve. *World Development, 32*(8), 1419-1439. doi:https://doi.org/10.1016/j.worlddev.2004.03.004
Stern, D. I., & Common, M. S. (2001). Is There an Environmental Kuznets Curve for Sulfur? *Journal of Environmental Economics and Management, 41*(2), 162-178. doi:https://doi.org/10.1006/jeem.2000.1132
Wang, Q., Wu, S.-d., Zeng, Y.-e., & Wu, B.-w. (2016). Exploring the relationship between urbanisation, energy consumption, and CO2 emissions in different provinces of China. *Renewable and Sustainable Energy Reviews, 54*, 1563-1579. doi:https://doi.org/10.1016/j.rser.2015.10.090
Weede, E. (1987). Urban Bias and Economic Growth in Cross-National Perspective. *International Journal of Comparative Sociology, 28*(1-2), 30-42.
Wu, Y., Shen, J., Zhang, X., Skitmore, M., & Lu, W. (2016). The impact of urbanisation on carbon emissions in developing countries: a Chinese study based on the U-Kaya method. *Journal of Cleaner Production, 135*, 589-603. doi:https://doi.org/10.1016/j.jclepro.2016.06.121
Zhang, C., & Lin, Y. (2012). Panel estimation for urbanisation, energy consumption and CO2 emissions: A regional analysis in China. *Energy Policy, 49*, 488-498. doi:https://doi.org/10.1016/j.enpol.2012.06.048