Journal of Cleaner Production 153 (2017) 331–341

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Does private investment in the transport sector mitigate the environmental impact of urbanisation? Evidence from Asia

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A R T I C L E I N F O

Article history:
Received 4 October 2016
Received in revised form
31 December 2016
Accepted 11 January 2017
Available online 18 January 2017

JEL Classifications:
O18
R42
G54
O53

Keywords:
Urbanisation
Transport sector
Private sector investment
CO_2 emission
Asia

A B S T R A C T

Urbanisation serves as a pillar for creating prosperous economies, but its impacts on infrastructure and the environment have been a concern for policy makers. There are numerous studies that examine the impact of urbanisation on the environment but no known study has analysed whether the impact of urbanisation on the environment is dependent on the characteristics of available infrastructure. To address this gap, this study uses the STIRPAT model, panel cointegration and fully modified ordinary least square (FMOLS) estimator as well as panel data of eight Asian countries to analyse whether private sector investment in the transport sector and transport infrastructure mode influences the impact of urbanisation on transport CO_2 emissions. We find that the effect of urbanisation on transport CO_2 emissions depends on the covariates in the model and interactions with other factors. Increase in income and population increases transport CO_2 emissions while technological improvements reduces CO_2 emissions from the transport sector. Private sector investment in the transport sector and availability of rail infrastructure reduce transport CO_2 emissions; and given the same level of urbanisation, Asian countries with more rail infrastructure and private sector investment in the transport sector tend to have lower CO_2 emission from the transport sector. Policy makers in Asia should make efforts to boost private sector participation in the transport sector and also promote the construction and improvement of rail infrastructure in order to reduce urbanisation-induced transport CO_2 emissions.

1. Introduction

The impressive economic growth of Asian economies in the past few decades, dubbed as the Asian miracle, has attracted attention globally and has been identified as a potential development pathway for other developing countries to follow (Chang, 2006; Lee et al., 2008). Over the past decades, Asian countries like China, Singapore, Korea, Malaysia and Taiwan have experienced considerable economic growth that enable them to place vast proportion of their population above the poverty line. For instance, GDP per capita (purchasing power parity) increased from 1990 to 2014 by 1248%, 300%, 273% and 169% in China, Korea, Singapore and Philippines respectively. Similarly, poverty and unemployment rates fell substantially in the region compared to other developing regions like sub-Sahara Africa. Other social and human development indicators such as under-five mortality, maternal mortality rates, institutional development, literacy rates, etc showed considerable improvements compared to their levels in the 1980s (UNDP, 2007). However, the improved economic performance and development also created some new challenges such as high urbanisation rates and environmental degradation (Jedwab and Vollrath, 2015; Martinez-Zarzoso and Maruotti, 2011).

Urbanisation rates increased rapidly in Asia more than any other region has ever experienced (UN-Habitat, 2013). The positive effects of urbanisation in Asia are documented in the literature (Browne, 2014). Yap and Thuzar (2012) suggest that cities in South-East Asia drive economic growth, supported by state investments in infrastructure, research and development and industrial clusters. This positive link between urbanisation and economic growth is also affirmed by Turok and McGranahan (2013). Cali and Menon (2009) analyse the impact of urbanisation on rural poverty in India, and find that the effect is positive but not strong. On the contrary, the negative impacts of urbanisation are also identified. UN-Habitat (2013) states that the Asia-Pacific region is urbanising faster

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http://dx.doi.org/10.1016/j.jclepro.2017.01.064

than any region in the world had ever done; and is increasingly accompanied by urban poverty, limited access to basic services, vulnerability and environmental degradation (Kundu, 2009). Hilderbrand et al. (2013) also associate rapid urbanisation in the Asia-Pacific region to low-quality and unsafe employment and high inequality level. Kraas (2007) emphasises the environmental problems associated with urbanisation, such as air and water pollution, waste disposal, ecological degradation, etc.

Environmental degradation in the region has increased significantly. According to the World Development Indicator, the CO_2 emissions per capita of the East-Asia and Pacific region rose by over 400% between 1960 and 2011, driven largely by China. As a whole, Asia currently has the highest level of CO_2 emission in the world; and CO_2 emissions from the combustion of fossil fuels are the major contributor to climate change. Thus, the increasing global attention and priority on environmental sustainability, especially in the aftermath of the Paris climate conference and adoption of the sustainable development goals (SDGs), has necessitated the need for the mitigation of environmental degradation globally and particularly in Asia.

One of the major challenges associated with urbanisation is the increased requirements for physical infrastructure such as transport, energy, water, and sanitation (Martinez-Zarzoso and Maruotti, 2011; Sadorksy, 2013). According to a recent research, there is a \$4.1–4.3 trillion annual investment gap between existing and required urban infrastructure (CCFLA, 2015). The demand for transport infrastructure in particular is significantly related to increasing urbanisation rates. Urbanisation drives mobility and transportation by increasing the demand for motorised traffic in urban centers, and between rural and urban areas. Given urbanisation levels, urban infrastructure will play an important role in determining the future of the climate. The transport sector is currently the second largest source of CO_2 emissions after the energy sector. According to the IEA (2014), the transport sector emitted 7.34 billion tons of CO_2 in 2013, which is equivalent to 23% of global CO_2 emission, and the level is expected to reach 9.3 billion tons by 2030. Meanwhile, urban transport infrastructure investments determine its features, including whether it is climate-friendly or vulnerable; and achieving sustainable urban development requires long-term planning, substantial investment and priority for low-emission intensity and climate-resilient transport infrastructure. Thus, it is imperative to study the impact of urbanisation on transport CO_2 emissions with special focus on the mode of transport infrastructure and financing. This is the primary objective of this study.

Numerous studies have been conducted on the impacts of urbanisation on the environment, specifically pollution and CO_2 emissions (Abesamis et al., 2013; Al-mulali et al., 2013; Al-Mulali et al., 2015; Xu and Lin, 2015a, 2015b, 2015c). Similar studies have investigated the determinants of CO_2 emissions (Dogan and Seker, 2016a, 2016b, 2016c; Jebli et al., 2016). But there are limitations in the literature that this study intends to address. The main contributions of this study to the literature are in two folds. First, we estimate the impacts of urbanisation on CO_2 emissions of the transport sector in Asia. From a careful review of the literature and to the best of the authors' knowledge, empirical studies that investigate the impacts of urbanisation on transport CO_2 emissions for the entire Asia are rare. Past studies like Hossain (2012), Kamal-Chaoui et al. (2011), Lin and Xie (2014a), Tang et al. (2015) only examine the impact of urbanisation on transport CO_2 emission in individual Asian countries, and mostly in China. Timilsina and Shrestha (2009) analyse transport CO_2 emissions in a number of Asian countries but exclude urbanisation from the explaining variables. This present study uses a panel data of eight Asian countries which include China, India, Malaysia, Thailand, Pakistan, Philippines, Vietnam and Indonesia. The selection of these countries is determined by data availability. Second, we investigate the impacts of the nature of transport infrastructure mode and investment on CO_2 emissions in the transport sector. This is the first known study to extend the literature to these fronts. In addition, we analyse whether the impacts of urbanisation on transport CO_2 emissions depend on the mode of transport infrastructure and the source of investment. Various studies have found that the impact of urbanisation partly depends on the level of development (Ke and Lin, 2015; Martinez-Zarzoso and Maruotti, 2011). But we posit that the impact may also be related to the mode of transport infrastructure and investment. The result is useful for policy makers on the appropriate policies to pursue to mitigate the environmental impacts of urbanisation vis-à-vis optimal transport infrastructure mode and investment structure.

In addition, we adopt a demonstrated analytical framework and recently developed estimation technique. We analyse the relationship between urbanisation and transport CO_2 emissions using the STIRPAT analytical framework, panel cointegration and fully modified OLS (FMOLS) estimator. The STIRPAT model is an important analytical tool for analysing the drivers of environmental changes, and it is useful for hypothesis testing unlike the IPAT and ImPACT models (Fan et al., 2006; York et al., 2003). The FMOLS estimator is used to estimate the coefficients of the impacts of urbanisation and the other variables on transport CO_2 emissions in Asia. This estimator is superior to conventional panel data estimators because it corrects for endogeneity and serial correlation in the model (Kao and Chiang, 2000; Pedroni, 2000). The panel cointegration and FMOLS are suitable for the analysis because they examine the long run relationship between the variables and estimates the coefficients of these variables. This is important given that the expected impacts of urbanisation and other economic factors on the environment are in the long run. These methods generate more reliable estimates of the impact of urbanisation and other variables on transport CO_2 emissions because they address endogeneity and serial correlation problems which are likely to undermine the results. Thus, the main objective of this study is to examine the relationship between urbanisation, rail transport infrastructure, and private sector investment in the transport sector and transport CO_2 emissions in Asia. The specific objectives are as follows:

(i) To analyse the impacts of urbanisation on transport sector CO_2 emissions in Asia
(ii) To determine whether the impacts of urbanisation on transport sector CO_2 emissions depends on the transport infrastructure mode and private sector investment in the sector.

The paper finds that the effect of urbanisation on CO_2 emissions from the transport sector depends on the variables in the model and the interactions of urbanisation with other factors. Increase in income and population also lead to increase in transport CO_2 emissions while technological advancement reduces transport emissions. Private sector investment and development of rail transport system also lead to reduction in transport CO_2 emissions. Given the same level of urbanisation, transport CO_2 tends to be lower in Asian countries with more rail infrastructure and private sector investment in the transport sector. The remainder of the paper is as follows: Section two reviews the relevant literature on urbanisation and the environment. The method of analysis and the analytical framework are the focus of section three. Section four presents and discusses the results of the empirical analysis while chapter five is the conclusion and policy implications of the study.

2. Brief review of the literature

The relationship between urbanisation and the environment has enjoyed distinguishable pedigree in the literature. Karaca et al. (1995) and Parikh and Shukla (1995) made it a subject of their work; and numerous studies have also been conducted on the subject thereafter. Al-mulali et al. (2013) analyse the relationship between urbanisation, energy consumption and CO_2 emissions in MENA countries from 1980 to 2009 using dynamic OLS method. The results show that there is a long run bi-directional relationship between urbanisation, energy consumption and emissions in the region, but the significance of the relationship varies among the countries and depends on their level of income. Dogan and Turkekul (2016) test the EKC hypothesis in the USA by examining the relationship between CO_2 emissions, urbanisation, output, energy consumption, trade and financial development. Poumanyvong and Kaneko (2010) find that urbanisation is associated with increased energy consumption in high income countries but low energy consumption in low income countries. Martinez-Zarzoso and Maruotti (2011) investigate the impacts of urbanisation on CO_2 emissions in a panel of eighty-eight developing countries and conclude that the impact is mixed, depending on the level of income. York et al. (2003) use the STIRPAT, IPAT and ImPACT tools to study the drivers of environmental impacts. The results of the study reveal that urbanisation is significantly associated with energy consumption and CO_2 emissions at the global level. Hossain (2011) study the relationship between CO_2 emissions, urbanisation, trade, openness, economic growth and energy consumption in a panel of newly industrialised countries. The results show that urbanisation contributes to the challenge of emissions. Sadorsky (2013) use the mean group estimators and common correlated effects estimators to analyse the impacts of urbanisation and industrialisation on energy intensity in developed countries. The study finds that the impact of urbanisation is mixed. In a latter study on sixteen emerging countries, Sardosky (2014) finds that the effect of urbanisation on CO_2 emissions is sensitive to the estimation technique, but mostly positive and insignificant. Liddle (2014) provide evidence on the impact of demographic dynamics on energy consumption and CO_2 emissions in a macro-level cross-country analysis. The study shows that urbanisation has a positive association with emissions. Ponce de Leon Barido and Marshall (2014) shows how CO_2 emissions are affected by urbanisation and environmental policy using data from eighty countries from 1983 to 2005. The study reveals that a 1% increase in urbanisation rates increases the level of emissions by 0.95%. Further analysis also shows that countries with strong environmental policy have less negative impacts. Elliot and Thomas (2014) examine the impact of urbanisation on local CO_2 emissions over time and space at the local level in the United States. At the global level, O'Neill et al. (2010) provide evidence that urbanisation substantially impacts emissions.

There are also enormous studies on the relationship between urbanisation and emissions in Asia (Kaneko et al., 2013). Xiangyang and Guiqiu (2011) analyse the dynamics of greenhouse gas emissions in China in the process of urbanisation and find that urbanisation significantly contributes to emissions in the country. Zhu et al. (2012) also explore the relationship between urbanisation and CO_2 emission in twenty emerging countries and find an inverted U-shaped relationship. Li et al. (2012) analyse the relationship between urbanisation and the environment in China and find s strong adverse impact of urbanisation on emissions. Lu and Huang (2011) study the impact of urbanisation on CO_2 emissions in China using Granger test and vector error correction model. They find that there is a long run relationship between urbanisation and emissions. Abesamis et al. (2013) estimates the effects of urbanisation on carbon emissions in the Philippines. The STIRPAT model is used by Dai and Liu (2011) to analyse the relationship between urbanisation and CO_2 emission in China. The results show a positive and significant association between the two variables. Xu and Lin (2015a) use nonparametric additive regression models to investigate the impacts of urbanisation and industrialisation on CO_2 emissions in China. The results show an inverted U-shaped relationship between urbanisation and emissions in the Eastern region; a positive U-shaped relationship in the Central region and an insignificant relationship in the Western region. Similar to Xu and Lin (2015a), Xu et al. (2016) analyse the impact of urbanisation on CO_2 emissions at the regional level using provincial data in China. The results show evidence of an inverted U-shaped relationship between urbanisation and CO_2 emissions in Central and Western China while there is a monotonous positive relationship in Eastern China. Ahmad et al. (2015) investigates CO_2 emissions from energy use in urban households in India. Hossain (2012) conducts an econometrics analysis of the relationship between CO_2 emissions, energy consumption, economic growth, trade and urbanisation in Japan using Johansen cointegration and ARDL bound tests. The impact of urbanisation on CO_2 emissions, though positive, is not statistically significant. In another study using the same method, Mohapatra and Giri (2015) examine the causal and cointegration relationship between economic variables and CO_2 emissions in India. The results show that economic growth and urbanisation significantly increases emissions. Kamal-Chaoui et al. (2011) associate the significant increase in CO_2 emissions in South Korea from 1990 to 2005 to high living standards, rapid industrialisation and urbanisation.

Some studies have gone further to assess the impacts of urbanisation on transport sector energy consumption and emissions (Lin and Xie, 2014a; Xu and Lin, 2015b). Poumanyvong et al. (2012) finds that urbanisation increases the level of energy use in the transport sector and the impact is larger for high income countries. Zhou et al. (2013) explore the relationship between transition of settlement morphology and energy use in the transportation sector in Xiamen Island in China. Liddle (2004) examine the impacts of population density and urbanisation on road transport energy consumption. The study finds that population density and urbanisations exerts a negative impacts on transport energy use, indicating that populated urban centers are associated with less demand for personal transport. Selvakkumaran and Limmeechokchai (2015) study CO_2 emissions in Thailand's transport sector using scenario simulation analysis. Dhar and Marpaung (2015) investigate the drivers of CO_2 emissions in Lebanon's transport sector using index decomposition analysis. Wiesenthal et al. (2015) assess the impact of R and D investment on transport innovation and emission. Wu and Huo (2014) explore the driving forces of CO_2 emissions in China's transport sector using index composition method while Tang et al. (2015) study the subject using bottom-up methods.

From the careful review of the recent relevant literature on the impacts of urbanisation on CO_2 emissions, some key points, limitations and gaps are noted. First, there is modest evidence that urbanisation significantly increases CO_2 emissions. Second, studies on Asia mostly focus on China and no study specifically focuses on the Asian region as a whole, despite UN-Habitat (2013) pointing out that the entire Asia-Pacific region is at risk of urbanisation-induced environmental degradation. The focus on China is understandable given her role as the largest CO_2 emitter in the world. However, the empirical evidence from China may not be applicable to other countries in the region due to heterogeneity arising from significant differences in resource endowment, level and pattern of economic development, technology advancements and country-specific factors. Thus, we conduct an empirical study for panel of Asian countries subject to data availability. Third, studies that empirically investigate the impacts of urbanisation on CO_2 emissions at the sectoral level in Asia are rare. Environmental protection and climate change mitigation requires national, but much more importantly, sectoral policies to account for the differential in sectoral contribution to CO_2 emissions. In this study, our analysis focuses on CO_2 emission from the transport sector in Asia. Fourth, no known study till date has empirically examined the impacts of private sector participation in the transport sector and infrastructure mode on transport CO_2 emissions. This present study is the first to extend the literature to these fronts. Fifth, most of the studies on the impact of urbanisation on CO_2 use inappropriate estimation techniques that neglect possible endogeneity issues resulting from the empirical models. This is even more critical given Sadorsky (2014)'s findings that the impact of urbanisation on the CO_2 emissions is sensitive to the estimation technique. Thus, using inappropriate technique would result in unreliable estimates and conclusions. In this study, we use panel cointegration method and FMOLS estimators because it addresses the problems of endogeneity and serial correlation.

3. Method and analytical framework

3.1. Econometric technique

This paper examines the impact of urbanisation on transport sector CO_2 emission in Asia. The econometric methodology adopted is the panel data analysis. According to Baltagi (2005), panel models control for heterogeneity, enhance the efficiency of estimation, identify and measure the effects that time series models could not, and reduce the effects of multi-collinearity. There are various techniques for estimating the coefficients of panel data models. The most commonly used methods are the pooled OLS, fixed and random effect models estimators. But these techniques are biased and produce inconsistent estimates when the variables are cointegrated. This leads to the development of new estimators that estimate the cointegration vectors of panel data. The new estimators include within and between-group estimators such as OLS estimators, fully modified OLS (FMOLS) estimators and dynamic OLS (DOLS) estimators (McCoskey and Kao, 1999; Phillips and Moon, 1999; Phillips and Hansen, 1990). They produce asymptotically unbiased, normally distributed coefficient estimates (Pedroni, 2000; Kao and Chiang, 2000). The OLS and DOLS are parametric methods, with the DOLS including the lagged first difference. On the other hand, the FMOLS is a non-parametric method for correcting endogeneity (Chaiboonsri et al., 2010). The OLS is biased and inconsistent when applied to cointegrated panels. While Pedroni (2000) find that DOLS has higher size distortions than FMOLS, Kao and Chiang (2000) show that FMOLS may be more biased than DOLS (Harris and Sollis, 2005). Ramirez (2007) on the other hand argued that the FMOLS method is preferred over the DOLS method for relatively small samples. Thus, in this paper, the relationship between urbanisation and transport CO_2 emission in Asia is estimated using the FMOLS estimation technique.

According to Pedroni (2000), the FMOLS estimator adjusts for heterogeneity in the fixed effects and the short term. Once the existence of cointegration among the variables has been established, the cointegration relationship can be estimated using the FMOLS. The advantage of the FMOLS is that it not only generates consistent estimates of the parameters in relatively small samples, but also addresses the problems of endogeneity in the cointegration regression and serial correlation in the residual, which results in asymptotically efficient estimation of the cointegrating vector. The FMOLS allows for greater flexibility in the presence of heterogeneity of the cointegrating vectors and yields better estimates than the conventional fixed and random effect methods. Hamit-Haggar (2012) posits that the FMOLS is the most appropriate method to apply to heterogeneous cointegrated panels. It produces the OLS estimates of the long run covariance matrices and then run another regression on corrected variables, where the correction factors are functions of the estimated long run variance matrices (Hlouskova and Osbat, 2009). According to Ramirez (2007), the FMOLS estimator for the i-th panel member is given in eq. (1) as follows:

$$\beta_i^* = (X_i'X_i)^{-1}\,(X_i'y_i^* - T\delta) \tag{1}$$

where y_i^* is the transformed endogenous variable, δ is a parameter for autocorrelation adjustment, and T is the number of time periods. For more on the form and expression of the FMOLS, see Basile et al. (2005), Caporale and Skare (2011) and Chaiboonsri et al. (2010).

3.2. Analytical framework and empirical model

The framework for the empirical model in this study is the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model developed by Dietz and Rosa (1997). It is used to describe the factors driving environmental changes. Specifically, the STIRPAT model shows how population growth, affluence and technology affect the environment. The STIRPAT model is expressed in eq. (2) as follows:

$$I_t = aP_t^bA_t^cT_t^de_t \tag{2}$$

where I represents environmental impact, typically measured in terms of CO_2 emission or other pollutant or environmental indicator, P denotes population, A represents a society's affluence, usually measured in terms of GDP, T is a technology index, a represents the constant term, b, c and d represent the elasticities of environmental impacts with respect to population (P), affluence (A) and technology (T) respectively, e_t is the error term and the subscript t denotes the year. Unlike the IPAT and ImPACT models which are accounting equations and assume proportionality in the functional relationship between the factors and environmental impacts, the STIRPAT model is a stochastic model and has been widely and successfully used in the literature to study the driving factors of environmental changes (York et al., 2003).

Taking the natural logarithm of both sides of eq. (2), and considering a panel of Asian countries, the STIRPAT model becomes:

$$\ln I_{it} = \ln a + b(\ln P_{it}) + c(\ln A_{it}) + d(\ln T_{it}) + e_{it}. \tag{3}$$

where I, P A, T, a, b, c, d and e are as defined in eq. (2), t is the time range of the data and i denotes the number of countries in the panel analysis. The choice of the proxy indicators is based on the literature (Liu et al., 2009; Wei, 2011; Xu and Lin, 2015a). In this study, environmental impact is measured by the level of CO_2 emissions from the transport sector; population is denoted by population size; affluence is indicated by GDP per capita; and technology index is proxied by energy intensity, which is measured as energy consumption divided by GDP. In addition to the core components of the model, the STIRPAT framework has also been used to analyse the impacts of other social and economic variables on the environment (York et al., 2003). Thus, to further investigate the relationship among urbanisation, private sector investment in the transport sector, rail infrastructure and transport CO_2 emission in Asia, we expand the STIRPAT model by incorporating urbanisation, rail infrastructure and private sector investment in the transport sector. The impact of energy consumption structure on CO_2 emissions has been extensively investigated in the literature (Cue et al., 2016;

Dogan et al., 2015; Lin et al., 2016; Wang et al., 2014), so it is not included in our model. Urbanisation (URB) is the variable of interest in the model and is indicated by the share of urban population in total population. The impact of private sector investment in the transport sector on transport CO_2 emission has not been investigated in the literature prior to this study. Private sector investment or participation in infrastructure could enhance efficient management of scare resources and operations of infrastructure utilities (Clark et al., 2005; Gunatilake and Carangal-San Jose, 2008). Also, because private sector participation in markets is accompanied by liberalised market prices, this tends to reduce inefficiency and waste. So we assess the impact of private sector investment on transport CO_2 emission. Finally, we include rail infrastructure, indicated by the length of rail lines in kilometre, in the model to assess the impact of transport infrastructure mode on CO_2 emission from the sector. Based on the analytical framework, the standard model for this study is presented in eq. (4) as follows:

$$\ln TCO_{2it} = \alpha_0 + \alpha_1 \ln POP_{it} + \alpha_2 \ln GDP_{it} + \alpha_3 \ln TI_{it} + \alpha_4 \ln URB_{it} + \alpha_5 \ln PSI_{it} + \alpha_6 \ln RAIL_{it} + e_{it} \tag{4}$$

where a, b, c, d, f, g and h in eq. (3) are replaced by mathematical notations α_0, α_1, α_2, α_3, α_4, α_5 and α_6 respectively in eq. (4).

The data used for the analysis are obtained from the World Development Indicators (WDI) of the World Bank. The World Development Indicators is an online database operated by the World Bank containing data on various economic indicators for all countries. Data on transport CO_2 emissions, population, GDP, technology index, urbanisation rates, private sector investment in the transport sector and rail infrastructure are all obtained from this source. The analysis is limited to eight Asian countries because of data availability issues. Only these eight countries have data on private sector investment in the transport sector for more than five year periods.

4. Results

This section presents and discusses the results of the analysis. It focuses on the data description, the techniques, interpretation and discussion of the results.

4.1. Descriptive statistics

The definition of the variables used in the paper is shown in Table 1. The table presents the variables, their codes and units of measurement.

Similarly, Table 2 shows the average values of transport CO_2 emissions, population, GDP per capita, technology index, urbanisation rates, rail infrastructure and private sector investment in the transport sector in all the eight countries under consideration. From Table 2, China has the highest average level of transport CO_2 emissions in Asia at 287.9 million metric tons, followed by India at 111.0 million metric tons. The sum of the average transport emissions of the remaining six countries is less than that of China. This indicates the status of China as the leading emitting country in Asia and the world. This is particularly due to her huge population and the associated demand for transport infrastructure. China and India occupy the first and second most populated countries in the world. For the period under review, the average population of China and India stands at 1264.4 million and 1133.2 million respectively. Comparatively, the average population for Indonesia, Malaysia, Pakistan, Philippines, Thailand and Vietnam are 214.6, 24.5, 145.9, 84.1, 60.8 and 85.1 million respectively. The average of GDP per capita shows that Malaysia has the highest GDP per capita at $5818.1 while Pakistan has the lowest average GDP per capita at $676.6. The average GDP per capita for China, Indonesia, India, Philippines, Thailand and Vietnam are $2027.3, $1410.0, $822.5, $1496.8, $2210.6 and $1089.3 respectively. Technological index is depicted by the ratio of energy consumption to GDP. It is usually referred to as energy intensity (the inverse of energy efficiency). The average technological index shows that Philippines has the highest energy intensity (10.3 Btu/$) while China carbon has the lowest energy intensity (3.8 Btu/$). Similar to GDP per capita, Malaysia has the highest average urbanisation rates at 63.6% among the eight countries in this study. This is followed for Philippines and Indonesia at 46.7% and 41.9%. India and Vietnam have the lowest urbanisation rates (29.1%) among the eight countries. India has the largest private sector investment in the transport sector with an average of $4747.2 million, followed by China at $2424.7 million. On the other extreme, Vietnam has the lowest average private sector investment in the transport sector for the time period covered. The level of private sector investment in the transport sectors in these countries may be largely attributed to the market potential, indicated by the population size, and availability of favourable policy conditions. India has the biggest rail infrastructure, measured by the length of rail tracks. The average rail length for India stands at 63391.2 km, followed by China at 59625.1 km. On the other hand, Philippines has the smallest rail infrastructure among the eight countries reviewed. The rail length for Indonesia, Malaysia, Pakistan, Thailand and Vietnam are 4862.3, 1730.3, 7852.5, 3988.1 and 2827 km respectively.

Table 3 below shows the full summary statistics of the variables. The mean of the variables in Table 3 relative to the individual mean for each country in Table 2 shows that there is a wide disparity among the countries in terms of the object of study and the variables of interest. Also, the large standard deviation confirms that large variation among the variables. Hence, there is the need to take note of the differences in the economic characteristics of the countries under consideration as well as the variables.

4.2. Panel unit root tests

Most series of economic variables are non-stationary and using such economic series for analysis would produce unreliable and

Table 1
Definition of the variables used in the study.

Variable	Definition	Units of measurement
TCO_2	CO_2 emission from the transport sector	Million metric tons
GDP	GDP per capita	US$
TI	Technology index	Btu per US$
URB	Urbanisation rates	Percent
POP	Population	Millions
PSI	Private sector investment in the transport sector	Million US$
RAIL	Rail infrastructure	Kilometre

Source: Authors' compilation

Table 2
Average of the variables for the case countries.

Country	Year	TCO_2	POP	GDP	TI	URB	PSI	RAIL
China	1990–2013	287.9	1264.4	2027.3	3.8	38.7	2424.7	59625.1
Indonesia	1990–2012	65.1	214.6	1410.0	9.0	41.9	463.81	4862.3
India	1996–2013	111.0	1133.2	822.5	6.6	29.1	4747.2	63391.2
Malaysia	1992–2013	31.6	24.5	5818.1	7.7	63.6	954.8	1730.3
Pakistan	1995–2010	28.4	145.9	676.6	7.9	34.0	283.9	7852.5
Philippines	1995–2013	24.6	84.1	1496.8	10.3	46.7	314.0	481.5
Thailand	1990–2004	42.4	60.8	2210.6	8.4	31.4	298.0	3988.1
Vietnam	2006–2010	24.7	85.1	1089.3	7.0	29.1	224.0	2827

Source: Authors' computation

Table 3
Summary statistics of the variables.

Variable	Obs	Mean	Std. dev	Min	Max
TCO_2	133	88.8	113.4	16.13	623.32
POP	142	433.0	511.0	19.2	1360.0
GDP	142	2124.6	2158.8	316.2	10973.7
TI	138	7.5	2.2	2.0	13.6
URB	142	41.3	12.2	26.4	73.3
PSI	112	1570.0	3180	0	20200
RAIL	121	23692.2	27661	456	66298

Source: Authors' computation

bias estimates (Cavaliere et al., 2015; Deng, 2014). Therefore, before proceeding to the estimation of the model, we test the stationarity of the economic time series. If the data are non-stationary (contain unit roots), they will be transformed to stationary series by differencing. Various high power tests have been developed to test for unit root in panel data. These tests are divided into two categories. The first category is the tests that assume that the different cross-section sequences have a common unit root process. The tests under this category include Levin-Lin-Chu (LLC) test (Levin et al., 2002), Hadri LM test (Hadri, 2000) and Breitung test (Breitung, 2000). The second category assumes that the cross-section sequences have different individual unit root process. They include Im-Pesaran-Shin (IPS) test (Im et al., 2003), Fisher-ADF and Fisher-PP tests (Choi, 2001). Because of their popularity and wide use in the literature, and given the heterogeneity among the countries in this study and the unbalanced panel, the IPS and Fisher-ADF tests are employed. The results are shown in Tables 4 and 5 below. From the results of the Fisher-ADF test, it can be seen that most of the variables are non-stationary at levels, but their first difference series are all stationary at 1% significance level. This is consistent for all the four statistics under the Fisher-ADF test. Similarly for the IPS test, most of the variables are non-stationary at level, but their first-difference series are stationary at either 1% or 5% significance levels. Thus, we test for the existence of long run relationship among the variables using Johansen-Fisher panel cointegration test.

4.3. Johansen-Fisher cointegration test

The Johansen-Fisher cointegration test, developed by Maddala and Wu (1999), is used to examine the existence of a long run relationship among transport CO_2 emissions, population, GDP per capita, technology, urbanisation, private sector investment in the transport sector and rail infrastructure in Asia. The Johansen-Fisher cointegration test uses the results of the trace statistics and maximum eigenvalues to test the cointegration ranks among the panel series, which is a distinct advantage over the Pedroni cointegration test (Pedroni, 2004) and Kao cointegration test (Kao, 1999). However, its results are sensitive to the lag length and trend specification. Thus, we allow the optimum lag length to be

Table 4
Results of Fisher-ADF panel unit root test.

Stationarity	Variables	p-statistic	z-statistic	L* statistic	Pm statistic
Levels	TCO_2	21.5509	−0.3791	−0.3744	1.4270
	POP	21.0033	−0.0308	−0.0665	1.3235
	GDP	15.8830	−0.5314	−0.6147	0.3559
	TI	10.6783	0.7225	0.7999	−0.6277
	URB	27.0672	−1.2766	−1.2297	2.4695
	PSI	63.7041***	−5.8010***	−6.6524***	9.3932***
	RAIL	39.0791***	−3.4988***	−3.8171***	4.7395***
1st Diff.	TCO_2	57.4978***	−4.4832***	−5.7217***	8.2203***
	POP	75.7556***	−6.1739***	−7.8721***	11.6707***
	GDP	66.6351***	−6.1997***	−7.0114***	9.9471***
	TI	44.1214***	−4.3652***	−4.5334***	5.6924***
	URB	30.7362***	−3.0792***	−3.0012***	3.1628***
	PSI	115.7704***	−8.9704***	−12.2207***	19.2328***
	RAIL	100.6198***	−8.4392***	−11.4969***	18.0894***

*** = significant at 1% level.
Source: Authors' computation (extracted from STATA)

Table 5
Results of Im-Pesaran-Shin unit root test.

Stationarity	Variable	W-stat	p-value
Levels	TCO_2	3.6261	0.9999
	POP	−3.9505***	0.0000
	GDP	3.3532	0.9996
	TI	5.2360	1.0000
	URB	−1.3170	0.0939
	PSI	−5.9222***	0.0000
	RAIL	−1.0148	0.1551
1st Diff.	TCO_2	−6.6414***	0.0000
	POP	−1.7290**	0.0419
	GDP	−5.4267***	0.0000
	TI	−3.7866***	0.0001
	URB	−4.9212***	0.0000
	PSI	−14.1294***	0.0000
	RAIL	−10.7929***	0.0000

, * = 5% & 1% significant level.
Source: Authors' computation (extracted from EVIEWS)

determined by the Akaike information criteria (AIC). The results of the Johansen-Fisher cointegration test are presented in Table 6 and indicate that the null hypothesis of no cointegration is rejected at 5% significance level as the p-values are less than 0.05. Thus, we conclude that there is a long run cointegration relationship among transport CO_2 emissions, population, affluence, technological development, urbanisation, rail transport infrastructure and private sector financing in the transport sector in Asia.

4.4. Fully modified ordinary least square (FMOLS) estimator

The results of the FMOLS regression is presented in Table 7. The result presents the coefficients, direction and significance of the impacts of the explanatory variables on transport CO_2 emissions in

Asia.

Model I shows the result of the FMOLS regression using only urbanisation as the explanatory variable. There is no significant relationship between urbanisation and transport CO_2 emissions, implying that urbanisation has no impact on emissions. But other control variables are not included in the model. In model II, population, GDP per capita and technology index are included in the model. From the results, only the coefficients of population, technology index and GDP per capita are significant, at 1% significance level. The coefficient of urbanisation is not significant. Model III and IV include the impacts of private sector investment in the transport sector and rail infrastructure, and the interaction between urbanisation and these variables respectively. It can be seen from model IV that the relationship between urbanisation and transport CO_2 emissions is positive and significant at 5% level but it is negative and insignificant in model III. This corroborates Sadorsky (2014)'s conclusion that the impact of urbanisation on CO_2 emissions varies with covariates and techniques. Furthermore, model IV shows that urbanisation does not have a unique effect on transport CO_2 emissions, but its effect depends on the interactions with other important factors such as transport infrastructure mode and nature of investment. In other words, the extent and direction to which urbanisation affect transport CO_2 is largely conditioned on other factors. This is in line with the study of Adams et al. (2016) which shows that the impact of urbanisation on environmental quality is largely due to the presence of quality institutions. In model IV, A 1% increase in urbanisation rates increases transports CO_2 emissions by 0.349%. This implies that after controlling for other important variables and interacting with other factors, urbanisation could have significant effect on the environment, through the transport sector emissions. Urbanisation could increase transport carbon emissions because of large-scale population movements and the transformation of the industrial structure. In the past decades, Asia has experienced high level of urbanisation due to economic development and the trend is expected to continue in the future. For example, it is projected that the population of key cities in South East Asia like Manila, Hanoi, Jakarta and Bangkok will reach 13.4, 5.78, 20.77 and 7.76 million respectively (ADB, 2008). Also, the once-strict household registration system in China, known as Hukou, has been fairly relaxed and has encouraged mass migration from rural areas to urban centers and cities. With the structural transformation from agriculture to industrialisation in lots of Asian countries, large scale migration from agriculture-dominant rural areas to industrialisation-led urban cities has led to increase in the demand for transportation and ultimately CO_2 emission from the sector (Phdungsilp, 2009). Furthermore, with urban expansion Asian cities will consume more resources and emit more CO_2 emissions. This result is in line with the results of Al-mulali et al. (2013) for MENA countries and Martinez-Zarzoso and Maruotti (2011) for a panel of developing countries.

The coefficient of GDP per capita is the largest (0.853), indicating that a 1% increase in income level leads to a 0.853% increase in emissions from the transport sector. This finding is in line with a priori expectation and results of past studies (Ke and Lin, 2015; Xu and Lin, 2015a, 2015b). It also suggests that Asian countries are still in the early stages of the environmental Kuznets curve (EKC) when economic development is still strongly associated with environmental degradation. Increase in GDP per capita implies an increase in the standard of living and this enables households to have the capability to purchase and consume more energy-using goods such as electrical appliances and transport facilities. People will be able to acquire more goods and services whose production and life cycle consume natural resources and impacts environmental sustainability. Specifically, increase in income leads to increase in the demand for private cars and transportation facilities. This is put in proper perspective by Gertler et al. (2013) which shows that efforts to ensure pro-poor growth in developing region will lead to increase in energy consumption and CO_2 emissions. For instance, Lin and Xie (2014b) states that turnover of the transport industry in China grew at an annual average of 8.2% between 1981 and 2010. Also, according to Xu and Lin (2015c), private vehicle stock in China increased from 6.25 million units in 2000 to 88.39 millions in 2012. These growths are not unconnected with the increase in the level of income and standard of living in China in recent decades. Similarly, economic growth in Malaysia in the region of 4–5% since the 1990s, driven largely by the development of agro-allied industries and manufacturing sector, has significantly increased CO_2 emissions from various sources such as energy use, industrialisation and transportation.

Population has the second largest impact on transports CO_2 emissions in Asia. A 1% increase in population size leads to a 0.817% increase in transport emissions. Although Asia has the largest population in the world, the increase in the size of the population coupled with the increase in income and standard of living witnessed in the region in the past decades have resulted in higher demand for transportation infrastructure and emissions. This result corroborates earlier findings by Timilsina and Shrestha (2009). They find that income growth and population are the major causes of increase in transport CO_2 emissions in China, India, Indonesia, Korea, Malaysia, Thailand, Sri Lanka and Pakistan. These factors alongside transport energy intensity also have significant impact on transport emissions in Bangladesh, Philippines and Vietnam. Also, Ahmad et al. (2013) find that population increase is the main driver of high CO_2 emissions in South Asian countries, supporting the findings of the current study.

Technology index has a significant negative relationship with transport CO_2 emissions in Asia. A 1% increase in the level of technological advancement leads to a 0.544% reduction in the level of transport CO_2 emissions. This indicates that improvement in transportation technology has the potential to significantly reduce CO_2 emissions from the transport sector. Specifically, reducing the energy intensity (increasing the energy efficiency) of transportation is crucial to achieving reduction in environmental degradation associated with urbanisation in Asia. In recent years,

Table 6
Johansen-Fisher panel cointegration test.

Hypothesized No. of CE(s)	Fisher Stat[a] (from Trace test)	p-value	Fisher Stat[a] (from max-eigen test)	p-value
None	68.74	0.0000	42.76	0.0000
At most 1	156.5	0.0000	72.28	0.0000
At most 2	132.1	0.0000	99.06	0.0000
At most 3	96.72	0.0000	66.64	0.0000
At most 4	322.7	0.0000	292.9	0.0000
At most 5	52.33	0.0000	32.36	0.0001
At most 6	31.86	0.0001	31.86	0.0001

[a] Probabilities are computed using asymptotic Chi-square distribution.

Table 7
Summary of the fully modified OLS (FMOLS) regressions.

Transport CO_2	(I)	(II)	(III)	(IV)
Urbanisation (URB)	−0.775	0.073	−0.181	0.349**
Population (POP)		0.672***	0.827***	0.817***
GDP per capita (GDP)		0.594***	0.851***	0.853***
Technology index (TI)		−0.454***	−0.551***	−0.544***
Private sector investment (PSI)			−0.058***	
Rail infrastructure (RAIL)			−0.096**	
Urbanisation*Private sector investment				−0.016***
Urbanisation*rail infrastructure				−0.024*
Intercept	6.857	−12.423	−14.105	−15.935
Adj. R^2	0.012	0.940	0.977	0.976

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

measures, innovations and technological advancements such as highway tax, bus rapid transits (BRT), hybrid vehicles, ride sharing, public bike schemes, electric bikes, vehicle quotas and fuel efficiency regulations have helped to reduce transportation-related CO_2 emissions in different parts of the world (UN-DESA, 2012).

The impacts of private sector investment in the transport sector and rail infrastructure on transport CO_2 emissions are depicted in model III. A 1% increase in private sector investment in the transport sector reduces transport CO_2 emissions by 0.058%. This shows that CO_2 emissions from the transport sector can be significantly reduced by encouraging private sector investment in the sector. This impact could be attributable to the fact that due to profit motives, private sectors are more efficient in the use of resources (Gunatilake and Carangal-San Jose, 2008; Roth, 2016). Also, private sector investment which correlates with market prices discourages unnecessary use of transport amenities. For example, encouraging the charging of tolls to recoup private sector investment in transport facilities may reduce the usage of private cars while encouraging public transport use. Private companies in the transport sector will have strong commercial incentives to focus on efficiency and this will translate to improved transport energy efficiency and lower emission from the sector. From a practice perspective, private sector companies operating passenger or haulage services may likely adopt the use of fuel-efficient vehicles which minimises their environmental impacts. Furthermore, driven by profit motives and quick turnover, private transport companies tend to devise means to be efficient and timely in their activities, and ultimately save energy resources. In addition, research and development and innovation associated with private sector investments may help to develop strategies to reduce the environmental impacts of urban transportation. Innovations such as ride sharing and taxi hailing apps like “uber” in the United States and “didi” in China are results of private sector initiatives in the transport sector.

There are many other channels through which private sector investment in the transport sector can reduce emissions from the sector directly or indirectly. If the costs of transport infrastructure are borne by users instead of with government subsidies, there is tendency for users of transport infrastructure to efficiently plan their use of such infrastructure (Roth, 2016). Efficient transport infrastructure that is less energy and emission-intensive could be developed by enabling private investors to supply transport infrastructure and facilities that beneficiaries are willing to pay for. Apart from reducing government expenditure on transport infrastructure, private investment in the transport sector and the consequent relation with users payment could reduce traffic congestion on roads and energy consumption from the transport sector. In addition, market-based instrument such as carbon taxes, cap and trade systems and fuel taxes could be complemented with the removal of fossil fuel subsidies, congestion charges and fuel economy standards. India and Brazil have been making modest achievements in promoting private sector investment in the transport sector (Leipziger and Lefevre, 2015; Puri, 2003), and other countries in Asia and other regions of the world should adapt some lessons from these countries and customise them to their local circumstances.

The development of rail transport infrastructure also helps to reduce CO_2 emissions from the transport sector. Also, a 1% increase in rail infrastructure leads to a 0.096% reduction in transport CO_2 emissions. This implies that increasing the amount of rail transport infrastructure reduces transport-related CO_2 emissions. Overall, rail transport is energy and carbon-efficient than road transport. Urban rail transport system runs on electricity compared to road transport that runs on gasoline, diesel and other fossil fuel. Though the source of the electricity used to power rail transport is crucial, its overall carbon footprint is lower than road transports. This is confirmed by Kahn Ribeiro et al. (2007), which shows that CO_2 emissions from road transport is more than double that of rail transport. The transport system in Asia has changed significantly in the past decades. According to Timilsina and Shrestha (2009), there has been a major shift in transport mode from rail to road in China since 2006, and air transport has also seen considerable share of passenger turnover at the expense of water transportation. Also, road transport still plays a dominant role in Korea, Vietnam and Pakistan. Considering that road transport accounts for the largest share of transport emissions, emphasis should be placed on other low emission transport system.

We further test the hypothesis whether the impact of urbanisation on transport CO_2 emissions depend on transport investment financing (PSI) and the mode of urban infrastructure (RAIL). The interaction terms between urbanisation and private sector investment in the transport sector (URB*PSI) and urbanisation and rail infrastructure (URB*RAIL) are negative and significant at 1 and 10% level respectively. These imply that whether urbanisation significantly affects the environment through the transport sector to some extent depends on the mode of available transport infrastructure and the role of private sector financing. Specifically, assuming a case of two countries in Asia with the same level of urbanisation rates; transport CO_2 emissions will be 0.016% lower for a country with 1% higher level of private sector investment in the transport sector. Similarly, transport CO_2 emissions will be 0.024% lower for a country with 1% higher level of rail infrastructure. By implications, private sector investment in the transport sector and development of rail infrastructure reduce the transport-related environmental impacts of urbanisation.

Generally, the transport sector possesses emission-reduction potentials in the context of urbanisation in Asian cities, and there have been efforts in recent years to optimise these potentials (Phdungsilp, 2009). Some of these measures include the development of master plan in large cities, promotion of mass transit systems, car pooling, improvements in engine efficiency, and encouraging the use of natural gas in vehicles in Thailand, Indonesia, Philippines and Vietnam.

5. Conclusions and policy implications

This paper investigates the impacts of urbanisation on transport CO_2 emissions in Asia, considering the role of private sector investment and rail infrastructure. Based on the STIRPAT analytical framework, panel cointegration method, FMOLS estimator and panel data of eight Asian countries, the objectives of this study are pursued. The results show that urbanisation could have an adverse effect on the environment as it increases CO_2 emissions from the transport sector. Increases in population and income levels are associated with increase in transport-related environmental problems. On the other hand, technological improvements reduce transport CO_2 emissions. Private sector participation in the transport sector and availability of rail infrastructure reduce CO_2 emissions from the transport sector. Finally, for two Asian countries with the same urbanisation rate, transport CO_2 emissions will be lower for the country with higher private sector participation in the transport sector and more rail infrastructure.

Based on the results of this paper the following policy suggestions are proposed. First, population growth in Asia should be managed in such a way that its impacts on transport CO_2 emissions is minimised. Second, since improvements in income and living standards are desirable development outcomes and are associated with urbanisation, policy makers in Asia should focus on pragmatic measures to ensure that economic development is balanced with urbanisation and environmental sustainability. This could be done by increasing awareness on the environmental impacts of household consumption and lifestyle patterns, promoting the use of energy and carbon-efficient goods, encouraging mass efficient and effective public transport systems, and initiating policies that discourage wasteful consumption. Third, technology advancement is found to reduce CO_2 emissions from the transport sector. There is need to promote technological innovation to expand possibilities for new and efficient low-carbon, climate-friendly transport infrastructure. This could be done by financing and investing in research and development, notably in low-carbon clean transport technologies. Though mobilising financing for low-carbon transport infrastructure can be challenging, creatively using fiscal space and private capital is essential. For example, imposing tax on carbon has the potential of raising substantial revenue to be invested in research and development and technological innovation. According to Qureshi (2016), only 5% of assets managed by banks and institutional investors globally are invested in infrastructure; and innovations to tap large chunks of these savings for infrastructure development should be promoted. Fourth, boosting private sector investment in the transport sector is essential for reducing transport CO_2 emissions. There is need for policies to catalyse a major upscale in private sector investment in the transport sector. Given the scale of transport infrastructure needs and fiscal constraints of governments in most countries, high proportion of new investments in the transport sector needs to emerge from the private sector. Policies and institutions should be put in place to reduce risks and costs of doing business and improve the efficiency of transport investment in order to encourage private participation in the sector. In addition, market incentives and reforms such as removal of gasoline and diesel subsidies and implementation of carbon pricing are crucial in this regard. Fifth, massive construction of new rail infrastructure in urban centers and improvement of existing ones are required. This is necessary to reduce the environmental footprint of urban transportation. This could be achieved by prioritising climate-friendly transportation system such as rail over road transport. This however requires massive financial investment, human capital, technical expertise and inter-country collaboration. Regional multilateral development banks such as the Asian Development Bank and Asian Infrastructure Investment Bank have important roles to play in this regards by helping to build capacities, mobilising financing and providing technical support on urban transport infrastructure projects.

This paper investigates the impact of urbanisation on CO_2 emissions from the transport sector, and whether the impact is dependent on the transport infrastructure mode and investment sources using panel data of eight Asian countries. We find that private sector investment in the transport sector and development of rail infrastructure reduces the environmental impacts of urbanisation. However, further studies should be conducted with more case studies and large panel data sets, especially in other regions, based on data availability to confirm the results of this study. In addition, the study only shows the impact of urbanisation, rail transport infrastructure and private sector investment on transport CO_2 emissions. Further studies should be extended to comprehensively examine the various channels and ways through which private sector investment in the transport sector reduces transport emissions.

Acknowledgements

The paper is supported by the Grant for Collaborative Innovation Center for Energy Economics and Energy Policy (No: 1260-Z0210011), Xiamen University Flourish Plan Special Funding (No: 1260-Y07200).

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