KOCHI UNIVERSITY OF TECHNOLOGY

Social Design Engineering Series *SDES-2017-8*

How does urbanization affect energy and CO2 emission intensities in Vietnam? Evidence from province-level data

Quan Anh Nguyen
Ministry of Energy, Vietnam

Makoto Kakinaka
Graduate School for International Development and Cooperation, Hiroshima University

Koji Kotani
School of Economics and Management, Kochi University of Technology
Research Center for Future Design, Kochi University of Technology

12th June, 2017

School of Economics and Management
Research Center for Future Design
Kochi University of Technology

How does urbanization affect energy and CO_2 emission intensities in Vietnam? Evidence from province-level data

Quan Anh Nguyen
Makoto Kakinaka
Koji Kotani

Abstract: Given the argument that urbanization is closely related to the economic growth with improved the quality of life, the role of urbanization on energy consumption and pollution emission has received attention from regulators and researchers. Recently, Vietnam, as one of the rapid growth emerging countries, has been undergoing a massive urbanization with massive increase in energy consumption and pollution. The purpose of this study is to discuss how urbanization affects energy and CO_2 emission intensities in Vietnam by using the province-level data over the period from 2010 to 2013. Our empirical analysis presents clear evidences supportive of the regional disparity of the effect of urbanization. For provinces with the low income level, urbanization would intensify energy and CO_2 emission intensities. In contrast, for provinces with the high income level, urbanization would mitigate energy and CO_2 emission intensities. This study also discusses related issues for three sectors of the Vietnamese economy: agricultural, industrial, and service sectors.

Keywords: urbanization; income level; energy and CO_2 emission intensities; Vietnam economy.

1 Introduction

Urbanization refers to the increase in the number of people who live in urban areas with the population shift from rural to urban areas, which results in the growth of urban areas horizontally or vertically. According to the United Nations, more than half of the world's population now lives in towns and cities, and this number is expected to reach about 5 billion by 2030. It is also acknowledged that urbanization is an inevitable process all over the world, which could cause socio-economic transformations with its positive and negative impacts on societies. Such urbanization issues are now more significant in emerging and developing economies including African and Asian countries. Vietnam, as a rapid-growing transition country, is also not an exception from urbanization. Since Vietnam introduced transition reforms from a centrally planned economy toward market-based socialism under a political and economic renewal campaign (Doi Moi) in 1986, urbanization has been an important phenomenon of socio-economic modernization, particularly in such metropolises as Hanoi, Da Nang, and Ho Chi Minh. According to the Vietnam Urban Development Report by the Ministry of Construction published in 2013, the country had around 480 urban areas in 1986, and the number of urban areas has reached 755 in 2013. In addition, the urban population was from 11.9 million in 1986 to roughly 30 million in 2013, which corresponds to around 30% of total population in the country.

As stressed in the Global Monitoring Report 2013 by the World Bank and International Monetary Fund (IMF), urbanization could help mitigate poverty issues and achieve the Millennium Development Goals (MDGs), but it could also lead to various social problems, including environmental problems, unless managed well. Among various issues related to urbanization, this study focuses on energy and environmental problems. One of the crucial agendas under urbanization is to reduce energy and emission intensities and thus to help mitigate environmental-related concerns. There are several contrasting arguments related to the effect of urbanization on energy and emission intensities in various fields such as city planning, ecological science, and urban economics. In general, one suggests the positive link of urbanization to these intensities due to the argument that urbanization promotes economic activities through intensified concentration of production and consumption, while the other insists the negative link due to the argument that urbanization brings about economies of scale with increased energy efficiency. Given these arguments, this study attempts to evaluate the relationship between urbanization and energy and emission intensities in a fast-growing transition country, Vietnam. The examination of the Vietnam case would provide some important implications about energy and environmental policies since most of developing and emerging countries share, or will share in their future development stages, similar features of urbanization and environmental-related issues.

Many empirical works have existed on how urbanization is associated with energy use and emission. Among them, some studies show the positive association of urbanization with energy use and emission at the national or regional level (see, e.g., Jones, 1989, 1991; York, Roza, and Dietz, 2003; Liu, 2009; Holtedahl and Joutz, 2004; Parikh and Shukla, 1995; Cole and Neumayer, 2004; York, 2007; Mishra, Smyth, and Sharma, 2009; Sadorsky, 2013), while other works find the negative linkage mainly at the city level (see, e.g., Liddle, 2004; Mishra, Smyth, and Sharma, 2009). Madlener and Sunak (2011) mention that urbanization changes patterns of energy consumption through various mechanisms, which differ considerably between developed and developing countries as well as within developing countries. Poumanyvong and Kaneko

(2010) discuss possible impacts of urbanization on the environment, including energy use and emissions, from the perspectives of three different arguments (ecological modernization, urban environmental transition, and compact city theories) at the national and city levels.

Sadorsky (2013) also reviews the effects of urbanization on energy use through several channels related to production, consumption, transport, and infrastructure. Urbanization changes production patterns by promoting economies of scale, the transfer from less energy intensive agriculture to energy intensive manufacturing, and the shift from decentralized rural energy sources, including wood burning, to centralized energy sources. In addition, urbanization also changes consumption patterns. Urbanization would increase wealthier households and thus enhance the demand for more energy intensive products, such as automobiles, at the early development stage, but it may increase the demand for more environmental-friendly products, such as eco-products, at the matured development stage. Moreover, urbanization brings about changes in transport patterns by motorizing people's commuting and transport of products among producers and consumers and thus changes the demand patterns for infrastructure. Mass public transport infrastructure is crucial for the transport and energy efficiency.

There have also been several empirical works that show heterogeneous effects of urbanization on energy use and emission. Since urbanization affects energy use and emission with positive and negative effects from various factors, the balance of the different effects determines the net impact of urbanization. Among them, Poumanyvong and Kaneko (2010) evaluate the impact of urbanization on energy use and emission at the country level over 99 countries during the period from 1975 to 2005 and observe that the impact depends on the income level. Urbanization decreases energy use in the low-income countries but increases energy use in the middle- and high-income countries. On the other hand, urbanization increases emission but its effect is the largest in the middle-income countries. The balance of the positive and negative effects of urbanization changes as the income level changes under the transition of the development stages. In addition, Li and Lin (2015) show that urbanization decreases energy consumption but increases emissions in the low-income group, while urbanization does not significantly affect energy consumption, but decreases the growth of emissions in the high-income group. Moreover, Martinez-Zarzoso and Maruotti (2011) also study the effect of urbanization on CO_2 emissions in developing countries during the period from 1975 to 2003 and find an inverted-U shaped relationship between urbanization and CO_2 emissions, where the emission elasticity of urbanization is positive for low-urbanized countries and negative for high-urbanized countries.

Urbanization is now a crucial issue with serious environment-related concerns in most developing countries, particularly high-growth emerging countries, like Vietnam, which typically face inter-regional discrepancy in terms of their development stages. However, to the best of our knowledge, empirical literature on the effect of urbanization on energy use and emission at the regional level within a developing country is rather scarce, although this issue has been studied from various aspects. Exception may include the work of Zhang and Lin (2012), which examines the regional differences in the effects of urbanization with province-level panel data in China during the period from 1995 to 2010 and presents that its positive effects on energy consumption and emission vary across regions facing different development stages. Thus, the main contribution of this study is to identify the regional differences in the effect of urbanization at the regional level within one of developing or emerging economies, Vietnam

To investigate how urbanization relates to energy consumption and emission in Vietnam, we conduct empirical analysis by using the unique panel dataset at the province level during the period from 2010 to 2013. This study considers energy and emission intensities as the dependent variables to examine the effects of urbanization for the whole country and each of three main sectors (industrial, agriculture, and service sectors) and to identify the regional as well as sector differences in its effects. The main results show that urbanization would reduce energy and emission intensities for the whole economy, but the urbanization effect depends highly on the income level in each region. Urbanization is positively associated with energy and emission intensities in low-income provinces, while it is negatively associated with energy and emission intensities in high-income provinces. The analysis by sector also presents the clear picture of the heterogeneous effects on energy and emission intensities in relation to the income level, except that the agriculture sector shows the insignificant effect of urbanization on emission intensity.

The analysis in this study confirms that the income level in a province, reflecting its development stage, would determine the direction of the effects of urbanization. More interestingly, our results seem to be consistent with, although looks in contrast to, those in Poumanyvong and Kaneko (2010) which suggest the positive and negative effects of urbanization on energy consumption for high-income and low-income countries, respectively. Since Vietnam is classified in the low-income country, our analysis showing the negative urbanization effects for the whole economy is consistent with the result of Poumanyvong and Kaneko (2010). The inconsistency of the relationship between the urbanization effect and the income level could originate from the regional-level analysis in our study and the national-level study in Poumanyvong and Kaneko (2010).

The rest of the paper is organized as follows. Section 2 presents the brief overviews of urbanization, energy consumption, and emission in Vietnam. Section 3 covers our empirical analysis, which describes data, methodology, and estimation results. This section also discusses the regional differences in the relationship between urbanization and energy and emission intensities in relation to the income level reflecting the regional development stage. Final section provides conclusion.

2 Overview of urbanization, energy, and emission in Vietnam

Vietnam has successfully achieved remarkable economic performance with the high growth since the Doi Moi political and economic reforms launched in 1986, although some pessimistic views existed at the initial stage. The recent country's per capita GDP growth has been among the fastest in the world with its average of 5.5 percent per year since 1990 and 6.4 percent per year during the 2000s. The country achieved the high growth rate even during the periods of the 1997 Asian Financial Crisis and the 2007-2008 Global Financial Crisis, which proves the success of the country's past and current economic policies. Accordingly, Vietnam is now classified as a lower-middle income group by the World Bank, and its income level measured by GDP per capita (current USD) has increased from around USD 100 in 1990 to around USD 1300 and USD 2000 in 2010 and 2014, respectively. In terms of per capita income, Vietnam's current position can be comparable to the income level of Japan in the late 1950s, Korea in the early 1970s, Thailand in the mid-1980s, and China in the late 1990s (see Figure

1). In addition to the income level, the country has a good education performance with high life expectancy and low maternal mortality ratio, compared with countries with the similar level of per capita income. Currently, the country's government is implementing structural reforms under the Socio-Economic Development Strategy (SEDS) 2011-2020, which targets the development of human resources, market institutions, and infrastructure.

The National Congress of the Communist Party of Vietnam announced ambitious plans in 2001 to accelerate industrialization and modernization and to bring the country into industrialized nations by 2020. Although the goal is too ambitious to achieve, the country has made a significant progress in changing economic structure in which the industrial contribution in GDP has increased over the last two decades. In fact, according to the General Statistics Office, the share of the industry and construction to GDP is 38.6 percent, while that of the agriculture is 18.5 percent in 2012 (see Table 1). However, many economists and policymakers share some concerns about the country's industrialization and its industrial policies. Tran and Doan (2010) discuss the role of industrialization in reforming economic and employment structure in Vietnam and suggest that the reforms has failed to shift redundant workers away from agricultural sector since most of the country's investment has been allocated to capital-intensive industries. Nguyen (2011) also examines industrial policy and performance of the industrial sector and observes that the State-led policy has not yet succeeded in achieving industrialization due partly to the encouragement of rent-seeking activities, the failure of creation of new comparative advantages, and poor quality of policy formulation. It is widely acknowledged that under on-going ASEAN economic integration, Vietnam should adopt an efficient industrialization strategy, where the industrial sector is a driving force for economic growth.

Recently, access to basic infrastructure particularly in major cities has improved substantially through significant government’s efforts with official development assistance (ODA) from developed countries. Currently, electricity is accessible to almost all households, and clean water and modern sanitation are available to more than 75 percent of all households. In addition, other types of infrastructure, such as the sewer system and the transportation system, has also received attention especially in urban areas. Transport infrastructure, including roads and bridges, has been improved with the expansion of its capacity, but traffic congestion associated with rapid increases in car and motorbikes and the deterioration of roads caused by disordered urban planning is still a major social problem in most urban areas. Many infrastructure projects have been implemented to improve the living standard in urban and rural areas through funds from ODA, although there still remain many infrastructure-related problems to be solved.

Like other developing and emerging countries, urbanization along with industrialization has prevailed with the rapid increase in scale in Vietnam. The number of urban areas in the country has increased significantly from 480 in 1986 to 729 and 755 in 2007 and 2012, respectively (World Bank, 2011). At the same time, urban population has also increased considerably. In 2000, total urban population in the country was 18.7 million, accounting for 24 percent of the national population. In 2012, this number has reached 28.4 million, accounting for 32 percent of the national population (see Figure 2). In particular, Hanoi and Ho Chi Minh have achieved thee most rapid urban expansion in Vietnam. According to General Statistics Office (2014) and Ministry of Construction (2013), the significant increase in urban population has stemmed mainly from the natural increase in urban areas, the migration from rural areas to urban areas, and the boundary expansion of urban areas. Such massive urbanization has made the available infrastructure system overloaded, leading to serious social problems, including energy distribution, environmental pollution, traffic congestion, and food security.

Vietnam is a resource abundant country with large reserves of primary energy resources, such as coal, oil, and natural gas, and with a high potential for renewable energy resources, such as hydropower, biomass, solar, and wind (see, e.g., Toan, Bao, and Dieu, 2011). In 2012, the total national primary energy supply was around 58.0 million tons of oil equivalent (Mtoe), and the shares of coal, crude oil and petroleum, gas, and hydropower generation to the total national primary energy were 26%, 27%, 14%, and 8%, respectively (Asian Development Bank, 2016). Concerning the demand side, the country is more energy intensive compared to those in other Southeast Asian countries (see, e.g., Do and Sharma, 2011; Toan, Bao, and Dieu, 2011; Nguyen, 2011; Tang, Tan, and Ozturk, 2016). In 2012, the total final energy consumption in the country was 49.3 Mtoe, and the shares of residential, transport, service, industrial, and agriculture uses were 33%, 24%, 3%, 39%, and 1% (Asian Development Bank, 2016). Do and Sharma (2011) mention that the total energy consumption in Vietnam is expected to increase to 146 Mtoe in 2025 due to the steady domestic development. The Energy Institute of Vietnam also reports that the estimated energy demand in 2035 is within a range between 182 and 214 Mtoe (see Table 2).

Since the supply has dominated the demand, the country has been a net energy exporter. Net energy exports increased from 0.2 Mtoe in 1990 to 22.0 Mtoe in 2006 and then declined due to increased domestic demand. In 2012, the country exported 18.0

Mtoe of energy, of which 9.4 Mtoe and 8.6 Myoe were crude oil and coal, respectively (Asian Development Bank, 2016). However, the rapid economic growth is expected to enforce the country to shift from a net energy exporter to a net energy importer in the future, which would give rise to energy security problems. Toan, Bao, and Dieu (2011) project that the country will experience a net deficit of over 28 Mtoe in 2020 and over 104 Mtoe in 2030, even assuming an increase in domestic production of oil, gas, and coal and the development of other energy resources, such as renewable energy and nuclear power, under government initiatives of energy policies. Their study also expects that renewable energy accounts for less than 10 percent of total energy in 2030 with a decreasing proportion from over 40 percent in 2005, as the country's economy develops.

Massive urbanization, along with industrialization, brings about various social problems, one of which is environmental pollution. Air pollution may be the most serious issue of environmental pollution, which often causes a lot of damage to human being and the atmosphere. It is typically caused by the injurious smoke emitted by automobiles, trains, factories, and other human activities. Examples include pollution gases, such as sulfur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), and nitrogen dioxide (NO_2), dust pollution, and even smoke from burning leaves and cigarettes. Vietnam's remarkable performance of its economic development with urbanization and industrialization has caused intense pressure on environmental issues. The quality of the environment in the country has steadily been deteriorated compared to other countries. The Environmental Performance Index (EPI) presents that the country is ranked 131th among 180 countries in the 2016 EPI ranking report. In particular, the country shows worse performance for air quality with negative effects on human health, water, and environmental burden of disease.

The National Environmental Report, published in 2013 by the Ministry of Natural Resources and Environment (MoNRE), assesses natural and human-made effects on air quality, air contamination, pollution management, and air protection measures. This report also illustrates that the country's economy has generated air pollution at the high level, e.g., nearly 667,000 tons of SO_2, 618,000 tons of NO_2, and 6.8 million tons of CO_2 annually. According to the University of Natural Resources and the Environment, 3-4 percent of the entire population currently suffers from respiratory problems caused by air pollution, and the fraction of people facing difficulties in breathing is 4-5 times higher in rapidly-growing urban cities with the high level of air pollution, including dusts, particles, and gases, such as Hanoi, Ho Chi Minh, and Haiphong than in rural areas.

3 Empirical analysis

This section discusses how urbanization relates to energy use and CO_2 emission in Vietnam by conducting empirical analysis with the province-level panel data covering 63 provinces during the period from 2010 to 2013.

3.1 Methodology and data

To empirically examine the effects of urbanization on energy use and CO_2 emission, this study follows the conventional method in the literature, such as Jones (1991) and Sadorsky (2013). Specifically, we estimate the following energy and emission intensities equations:

$$ENE_{it} = \alpha_0 + \alpha_1 URB_{it} + \alpha_2 URB_{it} \times INC_{it} + \alpha_3 INC_{it} + \sum_k \eta_k x_{kit} + \epsilon_{it},$$

$$CO2_{it} = \beta_0 + \beta_1 URB_{it} + \beta_2 URB_{it} \times INC_{it} + \beta_3 INC_{it} + \sum_k \gamma_k x_{kit} + \varepsilon_{it},$$

where ENE_{it} is energy intensity at province i in year t, $CO2_{it}$ is (CO_2) emission intensity, URB_{it} is the degree of urbanization, INC_{it} is the income level, x_{kit}'s are other control variables that are expected to affect energy and emission intensities, and ϵ_{it} and ε_{it} are the error terms with standard properties. Energy and emission intensities (ENE and $CO2$) in each province are calculated by the logs of the total energy consumption (toe) and the total CO_2 emission (ton) divided by provincial real GDP (thousand USD), respectively. The degree of urbanization (URB), which is our main explanatory variable, is measured by the log of the percentage of population living in urban areas. In addition, the income level (INC) is measured by the log of real GDP per capita (USD) at the province level, which generally reflects the development stage in the province. Table 3 presents the definitions of variables used in the empirical analysis.

Our main focus is on how the relationship between urbanization and energy and emission intensities is related to the development stage, which differs substantially across provinces in Vietnam, like other developing economies facing regional disparity and inequality. To capture this issue, we include the interaction term of urbanization and the income level ($URB \times INC$) in the model, which allows us to examine the dependency of the effect of the urbanization on the income level. More specifically, differentiating the energy and emission equations with respect to URB yields:

$$\frac{\partial ENE}{\partial URB} = \alpha_1 + \alpha_2 INC,$$

$$\frac{\partial CO2}{\partial URB} = \beta_1 + \beta_2 INC,$$

where the estimated coefficients on the income level, α_2 and β_2, determine the direction of the impact of the income level on the urbanization effect on energy and emission intensities, respectively. Several contrasting arguments have existed on the effects of urbanization on energy use and emission, i.e., intensified concentration of production and consumption brings about the positive and negative linkages of urbanization with energy use and emission. Given the argument that the development stage, reflected by the income level, determines the balance of the positive and negative effects, Poumanyvong and Kaneko (2010) evaluate the urbanization effect in relation to the income level by using panel data at the national level. Differently from the previous studies, we examine how urbanization's role changes over the different stages of economic development within Vietnam by using panel data at the province level.

Concerning other control variables, we include the log of the industrialization measure (IND), which is calculated by the industry value added as a percent of GDP, following the past empirical studies, such as Sadorsky (2013), on the effect of industrialization. This measure represents manufacturing specialization in each province (Blanchard, 1992). In addition, this study also includes the measure of foreign direct investment inflow (FDI) at the province level into our empirical models. The measure of foreign direct investment inflow (FDI), which is calculated by the log of one plus foreign direct investment divided by GDP, captures the spillover effects of production transfer and technology, including the introduction of green technology, from developed countries (see, e.g., Shahbaz, Nasreen, Abbas, and Anis, 2015). Moreover, the models take into account the labor market condition (UNE) and human capital (HUM) at the province level, which are measured by the logs of unemployment rate and the ratio of people that have high school education and higher, respectively. Furthermore, we also include country and year dummies to control for the country- and year-specific effects associated with various factors, such as geographic location, resource endowment, and energy prices. Wooldridge (2015) suggests that the inclusion of such dummies could mitigate heterogeneity bias and problems with possible spurious regression.

The province-level data of energy consumption and CO_2 emission are collected from the Energy Institute of Vietnam and the Ministry of Natural Resources and Environment, respectively. The other province-level data used in our empirical analysis is obtained from Local Statistical Yearbook (2010-2013). This study evaluates the urbanization effects on energy and emission intensities in relation to the income level for the whole economy and each of the three sector groups (industrial, agriculture, and service sectors) by applying three estimation methods: fixed effects (FE), Prais-Winsten (PW), and first-difference (FD) models. In the estimation for each sector, we use as the dependent variables the provincial levels of energy and emission intensities, which are calculated by the logs of the energy consumption (toe) and the CO_2 emission (ton) for each sector divided by the sector's value added (thousand USD), respectively. Table 4 presents the summary of statistics for variables used in our empirical analysis. Tables 5 and 6 show the correlation matrix of variables in the energy and emission intensities equations. It appears that the urbanization measure (URB) is generally less correlated with energy and emission intensities for the whole economy and each of the three sectors. For the whole economy, the correlation between ENE and URB is 0.111, and that between $CO2$ and URB is 0.130.

Tables 7, 9, 10, and 11 report the estimated results of the energy intensity equation for the whole economy and each of the three sectors. Tables 8, 12, 13, and 14 present the estimated results of the emission intensity equation. Following the procedure in the work of Poumanyvong and Kaneko (2010) on the urbanization effects, we first apply the FE estimation, since our sample may face the heterogeneity problem so that the OLS estimation could suffer from heterogeneity bias with a common constant term. The Wooldridge tests for autocorrelation in panel data (Wooldridge, 2002) suggest that our FE estimation could suffer from serial correlation. In addition, the modified Wald statistic for groupwise heteroskedasticity in the residuals of a fixed effects model (Greene, 2000) observes the presence of heteroscedasticity in our FE estimation. These results imply that the estimated results of the FE estimation could suffer from the biased problem. Thus, we conduct the PW estimation with panel-corrected standard errors to control for serial correlation of type AR(1), heteroskedascity, and cross-panel correlation.

In addition, we also verify our empirical results by applying the first-difference (FD) estimation, which could mitigate serial correlation problems (Wooldridge, 2015). In this estimation, we conduct the Wooldridge autocorrelation test (Wooldridge, 2002) and the Breusch-Pagan heteroskedasticity test (Breusch and Pagan, 1979) for each model. Once autocorrelation is identified, we apply the Newey-West corrected standard errors (Newey and West, 1987). If autocorrelation is not identified, and if the heteroscedasticity is identified, we apply the heteroscedasticity-consistent standard errors, as recommended by MacKinnon and White (1985). Moreover, we further apply the seemingly unrelated correlation regression (SUR) model for the robustness check, since the two error terms of the energy and emission intensities equations might be correlated each other. Table 15 shows the estimated results of the SUR estimation of the energy and emission intensities equations.

3.2 Results

This subsection presents the estimated results and their implications on how urbanization is associated with energy and emission intensities in relation to the income level or development stage for the whole economy and each of the three sectors (industrial, agriculture, and service sectors) in Vietnam.

3.2.1 The whole economy in Vietnam

Tables 7 and 8 present that without the interaction term of the urbanization measure and the income level, $\mathrm{URB} \times \mathrm{INC}$, the coefficients on URB are negative in both the energy and emission intensities equations, particularly for the PW estimation, although the FE and FD estimations show the insignificant results. The negative linkage of urbanization with energy intensity appears to be consistent with the result of Poumanyvong and Kaneko (2010) and Li and Lin (2015) in that urbanization decreases energy use in the low-income countries, including Vietnam. On the other hand, the negative linkage of urbanization with emission intensity is inconsistent with the result of Poumanyvong and Kaneko (2010) that observes that urbanization increases emissions although with a smaller magnitude in the low-income countries than the middle-income countries. However, once the interaction term $\mathrm{URB} \times \mathrm{INC}$ is included in the models, we can get a clear picture of the role of the income level in determining the urbanization effect on energy and emission intensities. Irrespective of the model choices, the coefficients on URB and $\mathrm{URB} \times \mathrm{INC}$ are significantly positive and negative, respectively, in both the energy and emission intensities equations. This implies that the urbanization effect depends highly on the income level, so that urbanization is positively associated with energy and emission intensities in the low-income provinces, while it is negatively associated with these intensities in the high-income provinces. That is, urbanization increases energy and emission intensities in the low-income provinces, but it decreases energy and emission intensities in the high-income provinces.

Possible explanation of the non-linear urbanization effects may be related to the contrasting arguments on the effect of urbanization. The positive association of urbanization originates mainly from the argument that urbanization promotes economic activities through intensified concentration of production and consumption, while the negative linkage comes mainly from the argument that urbanization brings about increased energy efficiency through economies of scale. In the low-income provinces, the former effect would dominate the latter, partly since their economic and industrial structures are still immature in the less development stage with lack of infrastructure, such as roads and bridges, so that they may not obtain enough benefit from economies of scale associated with urbanization. On the other hand, the latter effect dominates the former, as the income level increases with their development stage advanced due to increased benefit from economies of scale and improved energy efficiency. Various infrastructure projects, like the introduction of the public transportation system, might also help improve energy efficiency and mitigate environmental issues in the high-income regions. A simple calculation using the estimated results in Tables 7 and 8 suggests that the critical income level differentiating the direction of the urbanization effect is approximately $800 \sim 1000$ US dollars ($e^{6.7} \sim e^{6.9}$). Table 16 presents energy and emission intensity elasticities of urbanization, which are based on the estimated results and the income level of each province in 2013. The energy intensity elasticity ranges between -0.312 and 0.074, and the emission intensity elasticity ranges between

-0.141 and 0.015. Our estimated energy elasticity of urbanization is smaller than the results of developing countries in Sadorsky (2013).

Our empirical results also present that the coefficients on the income level, INC, are significantly negative for all models. With the consideration of the negative coefficients on the interaction term, the high-income provinces in the relatively advanced development stage are associated with the low levels of energy and emission intensities, and this negative income effect is intensified by advance of urbanization. The environmental Kuznets curve (EKC) hypothesis, although there are a lot of debates on its empirical validity, proposes an inverted U-shaped relationship between environmental degradation and per capita income, i.e., environmental degradation increases up to a certain level, an then decreases as income per capita increases (see Dinda, 2004, for a review on the EKC). The results of the negative relationship of the income level with emission intensity suggest that although per capita income level is still relatively low as a low-income country, the Vietnam society might already be in a right-side position of the environmental Kuznets inverted U-curve, where environmental degradation decreases as per capita income increases. Stern (2004) among many studies mentions that a particular innovation tends to be adopted in developing countries with a short lag once the innovation is adopted in developed countries. Thus, even for developing countries, like Vietnam, advanced green technology from developed countries could be adopted by domestic and multinational firms that are located mainly in the relatively high-income and urbanized provinces within the country.

It is widely acknowledged that the economic development of Vietnam depends on rapid industrialization since the early 1990s. Many studies, such as Samouilidis and

Mitropoulos (1984), Jones (1989, 1991), and Sadorsky (2013), find that industrialization leads to large energy consumption due mainly to the argument that the manufacturing industry with the high value added would be more energy intensive, compared to the traditional agriculture or basic manufacturing industries. Poumanyvong and Kaneko (2010) also incorporate the share of industrial activity as a measure of industrialization into the models and present the positive association of industrialization with energy consumption, particularly for the low- and middle-income countries, as well as with CO_2 emission, although less clear results about the emission models. Our estimated results in Tables 7 and 8 suggest that the coefficients on the industrialization measure, IND, are significantly positive, irrespective of the model choices, for the energy intensity equation, but those on IND are generally less significant for the emission intensity equation. These coincide with the results for the low-income countries, including Vietnam, in Poumanyvong and Kaneko (2010).

Concerning other control variables, the results show that the coefficients on foreign direct investment (FDI) are generally insignificant in both the energy and emission intensities equations. FDI, which is considered as one of the important sources for economic development, especially in developing countries, could give rise to possibly contrasting effects on energy use and pollution emission through several channels, such as the transfer of production units as well as advanced or green technology from advanced countries (see, e.g., Lan, Kakinaka, and Huang, 2012). Mielnik and Goldemberg (2002) find a clear decline in the energy intensity as FDI increases in developing economies, probably due to the leapfrogging over old-fashioned traditional technologies by adopting modern technologies associated with FDI. The insignificant result of FDI implies that the positive and negative effects of FDI on energy and emission intensities would be balanced and cancelled out each other in Vietnam.

In addition, the estimated results in Tables 7 and 8 present that the coefficients on unemployment rate (UNE) are generally insignificant, so that the labor market condition also has no clear effect on energy and emission intensities. Moreover, our empirical analysis shows somewhat contrasting results about the effect of human capital (HUM) in that the coefficients on HUM are positive in the energy intensity equation and negative in the emission intensity equation, although statistically significant only for the PW estimations. Possible justifications may include that increased energy intensity associated with improved human capital comes from an increase in the energy-intensive industry that generally requires skilled labor with highly-qualified education, while decreased emission intensity associated with improved human capital is due to the high incentive to adopt environmental-friendly technology which is often preferred by the public consisting of well-educated people.

3.2.2 Sector analysis

The previous subsection has discussed how urbanization is associated with energy and emission intensities in relation to the income level for the whole economy of Vietnam. In this subsection, we analyze the same issue for each of the three sectors, i.e., the industrial, agriculture, and service sectors. The model estimation follows the same procedure as in the previous subsection. Tables 9, 10, and 11 present the estimated results of the energy intensity equation for the industrial, agriculture, and service sectors. Similarly, Tables 12, 13, and 14 report the estimated results of the emission intensity equation for the industrial, agriculture, and service sectors. The estimated results are described as follows.

First, the results concerning the role of urbanization show that the urbanization effect on energy and emission intensities generally depends on the income level for the industrial and service sectors. Urbanization would increase energy and emission intensities in the low-income provinces, while it would decrease these intensities in the high-income provinces. The threshold income levels differentiating the direction of the urbanization effect on energy and emission intensities are estimated at around $e^{6.5} = 660$ US dollars in the industrial sector and at around $e^{7.0} = 1100$ US dollars in the service sector. On the other hand, for the agricultural sector, the urbanization effect on energy intensity relies on the income level, while that on emission intensity is independent of the income level. Energy intensity in the agriculture sector would be increased and decreased as urbanization prevails in the low-income and high-income provinces, respectively. However, the urbanization effect on emission intensity in the agriculture sector is insensitive to the income level, although the effect seems to be positive.

The threshold income level differentiating the direction of the urbanization effect on energy intensity in the agriculture sector is estimated at around $e^{7.6} = 2000$ US dollars. Table 16 presents energy and emission intensity elasticities of urbanization, which are based on the estimated results and the income level of each province in 2013, for each sector. The energy intensity elasticity ranges between -0.177 and 0.011, between -0.228 and 0.253, and between -0.711 and 0.318 for the industrial, agriculture, and service sectors, respectively. The emission intensity elasticity ranges between -0.132 and 0.007 and between -0.302 and 0.112 for the industrial and service sectors, respectively. The comparison of the threshold income levels among the three sectors reveals that the industrial sector has the lowest value, and then the service and agricultural sectors follow in order. This implies that the urbanization effect on energy intensity in the industrial sector tends to change from a positive region to a negative region at the early stage of development (i.e., at the relatively low income level), while the effect in the agricultural sector tends to change to a negative region at the later stage of development (i.e., at the relatively high income level). This finding could be justified by the argument that compared to the agricultural sector, urbanization would promote energy efficiency of production in the industrial sector, mainly manufacturing, at the earlier stage of development, since a new industrial technology innovated in developed countries is easily introduced in the industrial sector of developing countries (Stern, 2004).

Second, concerning the income effects, our empirical analysis generally presents the clear difference between the agriculture sector and other two sectors. For the industrial sector, the coefficients on INC and $\mathrm{URB} \times \mathrm{INC}$ are significantly negative for all estimations. For the service sector, the coefficients on $\mathrm{URB} \times \mathrm{INC}$ are significantly negative in the energy intensity equations for all estimations, and those on INC and $\mathrm{URB} \times \mathrm{INC}$ are significantly negative in the emission intensity equations for the PW estimation. These suggest that for the industrial and service sectors, energy and emission intensities would decrease with a rise in the income level, and in addition such a negative income effect is intensified as urbanization prevails. In contrast, for the agriculture sector, the coefficients on INC and $\mathrm{URB} \times \mathrm{INC}$ are significantly positive and negative, respectively, in the energy intensity equation for PW and FD estimations. Given the threshold urbanization level which is estimated at around $2.7 \sim 3.0$, the income effect on energy intensity is positive in less-urbanized provinces, while it is negative in highly-urbanized provinces. In the emission intensity equation for the agriculture sector, the coefficients on INC are significantly negative, although less clear, and those on $\mathrm{URB} \times \mathrm{INC}$ are insignificant. Thus, an increase in the income level would decrease emission intensity, independently of the urbanization level.

Third, the empirical analysis by sector also shows the clear sector difference in the effect of industrialization on energy and emission intensities. The results show that industrialization decreases energy and emission intensities in the industrial sector. In general, industrialization tends to increase energy intensity due to the fact that the industrial sector produces the high value added products, which would be more energy intensive (Jones, 1989, 1991). However, as industrialization prevails with increased concentration in the industrial activities, the energy efficiency in the industrial sector can be improved due to the enhanced benefit from scale economies. The negative effect of industrialization in the industrial sector confirms that the latter effect dominates the former. In contrast, the results also present that industrialization increases energy and emission intensities in the agriculture and service sectors. An industrialized economy might also promote economic activities in other sectors as the spillover effect, which could result in the increase in energy use in other sectors.

Finally, concerning other controls, the estimated results related to FDI effects suggest that FDI inflows decrease energy and emission intensities in the agriculture sector. On the other hand, FDI inflows increase energy intensity in the industrial sector and emission intensity in the service sector, although the corresponding estimated coefficients are significant only for the PW estimation. In addition, the analysis also presents that unemployment rates reflecting the labor market condition are positively associated with energy and emission intensities in the agriculture sector. At the same time, the results show that provinces with the high unemployment rate tend to face the low level of energy intensity in the industrial sector. Furthermore, our analysis observes that although some estimated results are less clear, provinces with high human capital are likely to incur high energy intensity in the industrial and agriculture sectors and high emission intensity in the agriculture sector but to achieve low emission intensity in the service sector.

4 Conclusion

The study has analyzed how urbanization is associated with energy and CO_2 emission intensities in relation to the income level, which reflects the development stage, by using the province-level panel data of Vietnam. The empirical analysis has been conducted not only for the whole country, but also for the three main sectors of the Vietnamese economy: the industrial, agriculture, and service sectors. This study is the first attempt which conducts empirical analysis on the urbanization effect on energy use and emissions in newly emerging countries, like Vietnam, with the full set of three main economic sectors at the province-level. In addition, this study has also examined the roles of other important factors, such as industrialization.

The main results have shown the negative effects of urbanization on energy and emission intensities with the relatively small magnitude for the whole economy in Vietnam. However, once we introduce the role of the income level in determining the urbanization effect, the results have shown a clear picture that such an urbanization effect depends highly on the income level in each province. Urbanization is positively associated with energy and emission intensities in low-income provinces, while it is negatively associated with energy and emission intensities in high-income provinces. The analysis by sector has also presented the clear evidence supportive of the heterogeneous effects on energy and emission intensities in relation to the income level.

In general, most developing countries suffer from reginal income inequality, which is one of the most important agenda for sustainable economic development. The existence of regional income inequality would enable our empirical findings to help understand the regional differences in the role of urbanization in identifying energy and environmental issues in Vietnam and other emerging countries. In addition, our results in this study contribute not only to the literature but also to encourage policymakers and urban planners to pay attention to the urbanization effect on energy and environmental issues for appropriate policy planning to promote sustainable economic development with environmental protection.

References

Asian Development Bank (2016). Viet Nam: Energy sector assessment, strategy, and road map. Asian Development Bank, Mandaluyong City, Philippines.

Blanchard, O., 1992. Energy consumption and modes of industrialization: Four developing countries. Energy Policy 20, 1174-1185.

Breusch, T.S., Pagan, A.R., 1979. A simple test for heteroscedasticity and random coefficient variation. Econometrica 47, 1287-1294.

Cole, M.A., Neumayer, E., 2004. Examining the impact of demographic factors on air pollution. Population and Environment 26, 5-21.

Dinda, S., 2004. Environmental Kuznets curve hypothesis: A survey. Ecological Economics 49, 431-455.

Do, T.M., Sharma, D., 2011. Vietnam's energy sector: A review of current energy policies and strategies. Energy Policy 39, 5770-5777.

General Statistics Office. (2014). Statistical year book 2014. Statistics Publishing House, Hanoi, Vietnam.

Greene, W.H., 2000. Econometric Analysis, Fourth Edition. Prentice Hall, New Jersey.

Holtedahl, P., Joutz, F.L., 2004. Residential electricity demand in Taiwan. Energy Economics 26, 201-224.

Jones, D.W., 1989. Urbanization and energy use in economic development. Energy Journal 10, 29-44.

Jones, D.W., 1991. How urbanization affects energy-use in developing countries. Energy Policy 19, 621-630.

Lan, J., Kakinaka, M., Huang, X., 2011. Foreign direct investment, human capital and environmental pollution in China. Environmental and Resource Economics 51, 255-275.

Li, K., Lin, B., 2015. Impacts of urbanization and industrialization on energy consumption/CO_2 emissions: Does the level of development matter? Renewable and Sustainable Energy Reviews 52, 1107-1122.

Liddle, B., 2004. Demographic dynamics and per capita environmental impact: Using panel regressions and household decompositions to examine population and transport. Population and Environment 26, 23-39.

Liu, Y., 2009. Exploring the relationship between urbanization and energy consumption in China using ARDL (autoregressive distributed lag) and FDM (factor decomposition model). Energy 34, 1846-1854.

MacKinnon, J., White, H., 1985. Some heteroskedasticity-consistent covariance matrix estimators with improved finite sample properties. Journal of Econometrics 29, 305-325.

Madlener, R., Sunak, Y., 2011. Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management? Sustainable Cities and Society 1, 45-53.

Martínez-Zarzoso, I., Bengochea-Morancho, A., Morales-Lage, R., 2007. The impact of population on CO_2 emissions: Evidence from European countries. Environmental and Resource Economics 38, 497-512.

Mielnika, O., Goldemberg, J., 2002. Foreign direct investment and decoupling between energy and gross domestic product in developing countries. Energy Policy 30, 87-89.

Ministry of Construction (2013). Vietnam Urban Development Report 2013 (Báo cáo tình hình phát triển đô thị năm 2013).

Mishra, V., Smyth, R., Sharma, S., 2009. The energy-GDP nexus: evidence from a panel of Pacific Island countries. Resource and Energy Economics 31, 210-220.

Newey, W.K., West, K.D., 1987. A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. Econometrica 55, 703-708.

Nguyen, H.L. (2011). Role of the State in industrial upgrading in Vietnam. Development Strategy Institute, Ministry of Planning and Investment, Vietnam.

Parikh, J., Shukla, V., 1995. Urbanization, energy use and greenhouse effects in economic development: Results from a cross-national study of developing countries. Global Environmental Change 5, 87-103.

Poumanyvong, P., Kaneko, S., 2010. Does urbanization lead to less energy use and lower CO_2 emissions? A cross-country analysis. Ecological Economics 70, 434-444.

Sadorsky, P., 2013. Do urbanization and industrialization affect energy intensity in developing countries? Energy Economics 37, 52-59.

Shahbaz, M., Nasreen, S., Abbas, S., Anis, O., 2015. Does foreign direct investment impede environmental quality in high-, middle-, and low-income countries? Energy Economics 51, 275-287.

Samouilidis, J.E., Mitropoulos, C.S., 1984. Energy and economic growth in industrialized countries: The case of Greece. Energy Economics 6, 191-201.

Stern, D.I., 2004. The rise and fall of the environmental Kuznets curve. World Development 32, 1419-1439.

Tang, C.F., Tan, B.W., Ozturk, I., 2016. Energy consumption and economic growth in Vietnam. Renewable and Sustainable Energy Reviews 54, 1506-1514.

Toan, P.K., Bao, N.M., Dieu, N.H., 2011. Energy supply, demand, and policy in Viet Nam, with future projections. Energy Policy 39, 6814-6826.

Wooldridge, J.M., 2002. Econometric Analysis of Cross Section and Panel Data. MIT Press, Cambridge, MA.

Wooldridge, J.M., 2015. Introductory Econometrics: A Modern Approach, Sixth Edition. South-Western Pub.

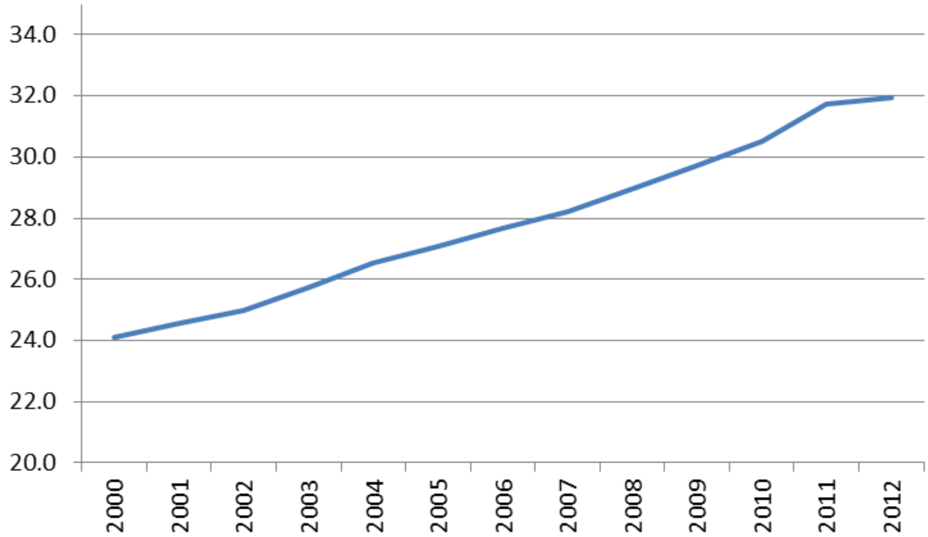
World Bank. (2011). Vietnam Urbanization Review: Technical Assistance Report. World Bank.

York, R., 2007. Demographic trends and energy consumption in European Union Nations, 1960-2025. Social Science Research 36, 855-872.

York, R., Rosa, E.A., Dietz, T., 2003. STIRPAT, IPAT and ImPACT: Analytical tools for unpacking the driving forces of environmental impacts. Ecological Economics 46, 351-365.

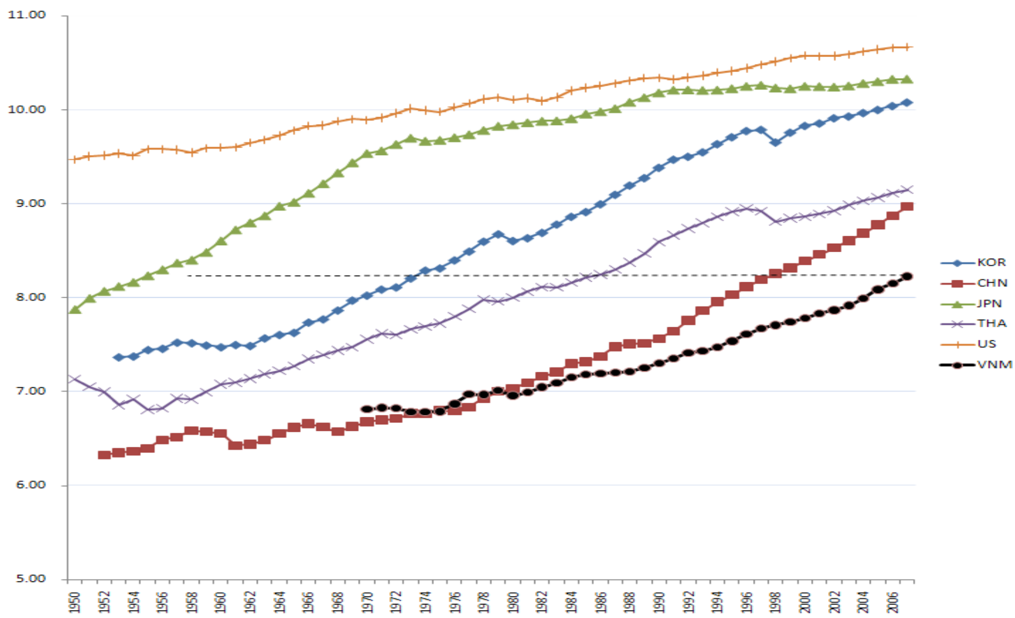
Zhang, C., Lin, Y., 2012. Panel estimation for urbanization, energy consumption and CO_2 emissions: A regional analysis in China. Energy Policy 49, 488-498.

Figure 1: Fraction of urban population



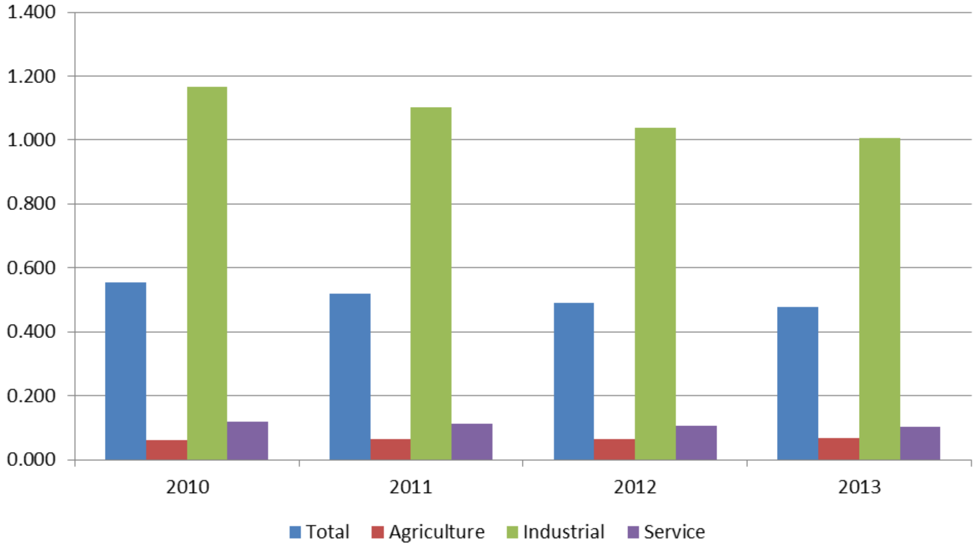
Source: General Statistical Office (GSO)

Figure 2: Comparison of per capita GDP (in log scale)



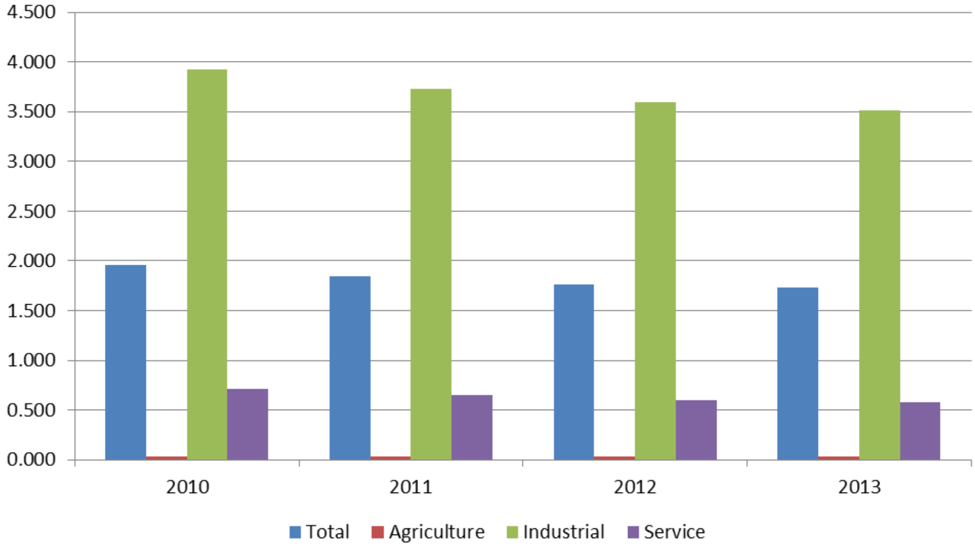
Source: World Bank Indicator

Figure 3: Energy intensity



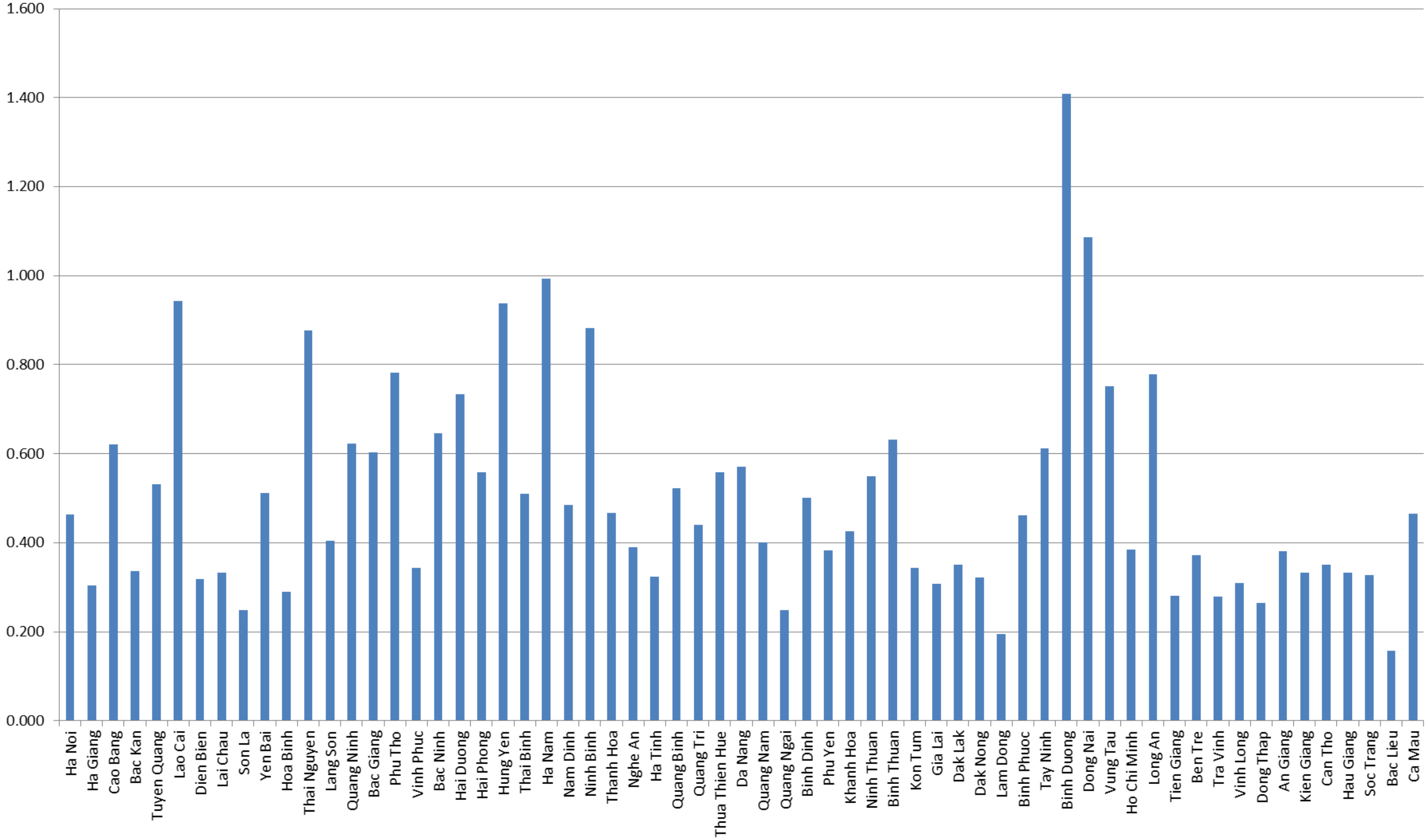
Notes: Energy intensity is calculated by energy consumption (toe) divided by gross domestic product (thousand VND).

Figure 4: Emission intensity



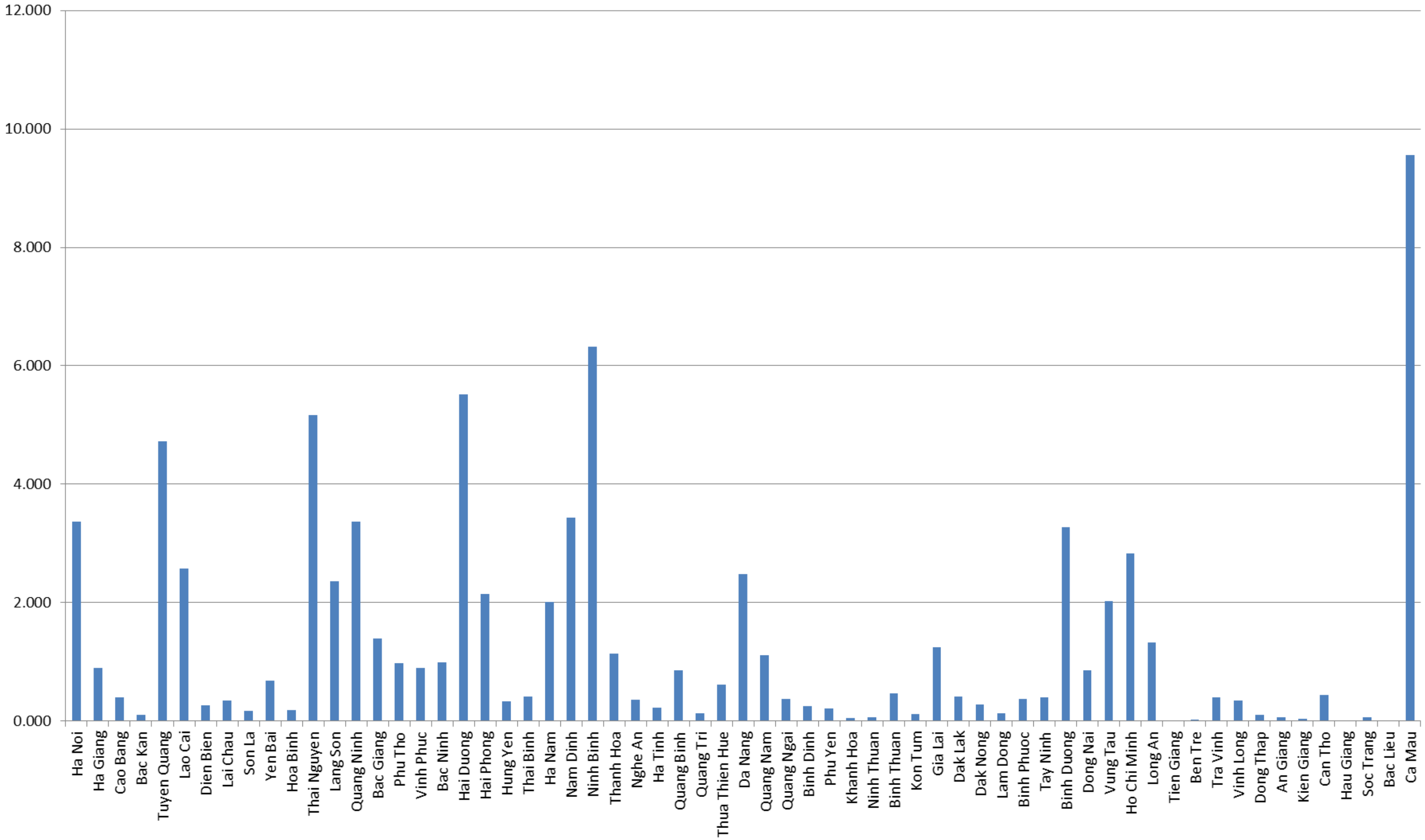
Notes: Emission intensity is calculated by emission gas (ton) divided by gross domestic product (million VND).

Figure 5: Energy intensity



Notes: Average over the sample period. Energy intensity is calculated by energy consumption (toe) divided by gross domestic product (thousand VND).

Figure 6: Emission intensity



Notes: Average over the sample period. Emission intensity is calculated by emission gas (ton) divided by gross domestic product (million VND).

Table 1: Real GDP share by industry 2005 – 2012

	2005	2006	2007	2008	2009	2010	2011	2012
Agriculture	21.58	20.94	20.32	20.13	19.46	18.89	18.50	18.05
Industry	38.12	38.23	38.31	37.76	37.96	38.23	38.39	38.57
Services	40.31	40.84	41.37	42.11	42.57	42.88	43.12	43.38

Source: General Statistical Office (GSO)

Table 2: Energy demand forecast by sector for period to 2035

	2015	2020		2025		2030		2035	
		Base	High	Base	High	Base	High	Base	High
Industry	24,325	34,402	37,344	46,260	52,023	60,499	69,720	77,396	90,252
Agriculture	668	757	751	824	831	879	899	934	960
Transport	15,286	22,811	25,247	33,311	37,897	47,559	55,620	66,558	79,072
Service - Trade	2,254	3,804	4,385	5,283	6,613	7,980	10,064	11,414	14,528
Residential	16,798	18,582	19,526	20,648	22,628	23,497	26,151	26,250	29,271
Total	59,330	80,356	87,253	106,328	119,992	140,415	162,454	182,552	214,083

Source: Energy Institute of Vietnam
Note: Unit: kTOE

Table 3: Description of the variables in the period 2010 – 2013

Variable	Name of variable	Definition	Data source
ENE	Energy intensity	Energy consumption divided by real GDP	Energy Institute of Vietnam
CO2	CO2 emission intensity	CO2 emission divided by real GDP	Ministry of Natural Resources and Environment
INC	Income level	Real GDP per capita	Local statistical yearbook (2010 - 2013)
IND	Industrialization	The ratio of the industry's value added to GDP	Local statistical yearbook (2010 - 2013)
URB	Urbanization	The ratio of the population living in urban areas	Local statistical yearbook (2010 - 2013)
FDI	FDI	One plus FDI at constant price 2010 divided by real GDP	Local statistical yearbook (2010 - 2013)
UNE	Unemployment rate	Unemployment rate	Local statistical yearbook (2010 - 2013)
HUM	Human capacity	The ratio of population who has education of high school or upper	Local statistical yearbook (2010 - 2013)

Note: All values are in terms of the logarithm.

Table 4: Summary statistics

	Obs	Mean	Std. Dev.	Min	Max
ENE					
Total	252	-0.786	0.438	-1.954	0.479
Industrial sector	252	-0.009	0.725	-2.324	1.041
Agriculture sector	252	-5.096	2.214	-10.580	-0.199
Service sector	252	-2.347	1.164	-5.838	-0.116
CO2					
Total	252	-0.763	1.706	-5.878	2.310
Agriculture sector	252	0.150	1.582	-4.837	3.036
Industrial sector	252	-4.887	2.086	-10.537	-1.176
Service sector	252	-4.934	3.038	-10.661	2.786
INC	252	6.931	0.504	5.870	9.076
URB	252	3.133	0.531	2.267	4.469
IND	252	3.516	0.406	2.447	4.461
FDI	229	0.051	0.089	0.000	0.879
UNE	229	0.497	0.646	-1.470	1.900
HUM	229	1.491	0.443	0.708	3.122

Note: All values are in terms of the logarithm.

Table 5: Correlation matrix (energy intensities)

	ENE	ENEI	ENEA	ENES	INC	URB	IND
ENE	1.000						
ENEI	0.571	1.000					
ENEA	0.055	-0.183	1.000				
ENES	0.020	-0.256	0.276	1.000			
INC	0.061	0.007	0.225	-0.215	1.000		
URB	0.111	-0.021	0.155	-0.011	0.574	1.000	
IND	0.430	-0.163	0.070	-0.187	0.407	0.211	1.000

Notes: ENEI, ENEA, and ENES represent energy intensity (ENE) in the industrial, agriculture, and service sectors, respectively.

Table 6: Correlation matrix (emission intensities)

	CO2	CO2I	CO2A	CO2S	INC	URB	IND
CO2	1.000						
CO2I	0.945	1.000					
CO2A	0.371	0.280	1.000				
CO2S	0.370	0.199	-0.011	1.000			
INC	0.038	-0.118	0.177	0.272	1.000		
URB	0.130	0.085	0.172	0.220	0.574	1.000	
IND	0.428	0.211	0.402	0.141	0.407	0.211	1.000

Notes: CO2I, CO2A, and CO2S represent emission intensity (CO2) in the industrial, agriculture, and service sectors, respectively.

Table 7: Estimation results: Energy intensity (Whole economy)

	FE				PW				FD			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
URB	-0.038	0.937**	-0.047	0.879**	-0.035*	0.966***	-0.045**	0.896***	-0.021	1.053***	-0.025	0.979***
	(0.042)	(0.400)	(0.039)	(0.399)	(0.018)	(0.094)	(0.018)	(0.070)	(0.063)	(0.283)	(0.031)	(0.300)
URB × INC	-	-0.139**	-	-0.131**	-	-0.142***	-	-0.133***	-	-0.153***	-	-0.142***
		(0.054)		(0.054)		(0.013)		(0.009)		(0.039)		(0.041)
INC	-1.019***	-0.580**	-1.086***	-0.665***	-1.019***	-0.570***	-1.085***	-0.658***	-1.020***	-0.549***	-1.061***	-0.615***
	(0.110)	(0.231)	(0.111)	(0.231)	(0.044)	(0.059)	(0.072)	(0.077)	(0.067)	(0.148)	(0.059)	(0.155)
IND	0.179***	0.120***	0.170***	0.117***	0.173***	0.113***	0.165***	0.113***	0.116***	0.080***	0.106***	0.076**
	(0.042)	(0.030)	(0.045)	(0.032)	(0.024)	(0.020)	(0.029)	(0.021)	(0.029)	(0.028)	(0.032)	(0.031)
FDI	-	-	0.044	0.045	-	-	0.045	0.046*	-	-	0.043	0.034
			(0.045)	(0.038)			(0.036)	(0.026)			(0.036)	(0.032)
UNE	-	-	-0.012	-0.016	-	-	-0.010	-0.014**	-	-	-0.002	-0.006
			(0.011)	(0.011)			(0.008)	(0.006)			(0.007)	(0.007)
HUM	-	-	0.045	0.049	-	-	0.044***	0.046***	-	-	0.022	0.023
			(0.043)	(0.041)			(0.015)	(0.015)			(0.020)	(0.019)
Constant	5.833***	2.973*	6.217***	3.367*	6.570***	5.635***	6.037***	3.222***	0.026***	0.049***	0.031***	0.031***
	(0.873)	(1.676)	(0.889)	(1.701)	(0.412)	(0.439)	(0.548)	(0.506)	(0.006)	(0.006)	(0.005)	(0.004)
R-squared	0.836	0.853	0.842	0.857	0.997	0.997	0.997	0.997	0.646	0.687	0.656	0.690
Modified Wald	6.7e+05***	1.4e+05***	3.1e+05***	5.2e+04***	-	-	-	-	-	-	-	-
Autocorrelation	131.46***	183.40***	101.47***	143.40***	-	-	-	-	-	-	-	-
Obs.	252	252	229	229	252	252	229	229	189	189	171	171

Notes: (1) Robust standard errors for FE and panel-corrected standard errors for PW are shown in parentheses. For FD, robust standard error, robust heteroscedasticity-consistent standard error, or Newey-West standard error are shown in parentheses, depending on the Wooldridge test for autocorrelation in panel data, Breusch-Pagan test for heteroskedasticity. (2) *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 8: Estimation results: Emission intensity (Whole economy)

	FE				PW				FD			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
URB	-0.023	0.420***	-0.029	0.356**	-0.024***	0.410***	-0.029***	0.349***	-0.025	0.357***	-0.027	0.308***
	(0.030)	(0.150)	(0.029)	(0.153)	(0.009)	(0.051)	(0.009)	(0.066)	(0.018)	(0.110)	(0.018)	(0.113)
URB × INC	-	-0.063***	-	-0.055**	-	-0.062***	-	-0.054***	-	-0.054***	-	-0.048***
		(0.021)		(0.021)		(0.007)		(0.010)		(0.015)		(0.016)
INC	-1.049***	-0.849***	-1.052***	-0.877***	-1.045***	-0.850***	-1.050***	-0.877***	-1.016***	-0.848***	-1.016***	-0.867***
	(0.036)	(0.079)	(0.039)	(0.079)	(0.022)	(0.027)	(0.030)	(0.045)	(0.023)	(0.056)	(0.025)	(0.058)
IND	0.040**	0.013	0.032	0.010	0.037***	0.012*	0.030***	0.009	0.021	0.008	0.015	0.005
	(0.019)	(0.015)	(0.020)	(0.017)	(0.010)	(0.007)	(0.011)	(0.007)	(0.013)	(0.013)	(0.015)	(0.015)
FDI	-	-	0.001	0.002	-	-	0.002	0.002	-	-	-0.002	-0.005
			(0.018)	(0.016)			(0.012)	(0.009)			(0.019)	(0.018)
UNE	-	-	0.0002	-0.002	-	-	0.000	-0.001	-	-	0.000	-0.001
			(0.004)	(0.004)			(0.002)	(0.002)			(0.003)	(0.002)
HUM	-	-	-0.011	-0.009	-	-	-0.010**	-0.009**	-	-	-0.006	-0.005
			(0.014)	(0.015)			(0.005)	(0.003)			(0.007)	(0.007)
Constant	6.512***	5.210***	6.459***	5.225***	8.703***	8.925***	9.305***	9.151***	0.043***	0.037***	0.043***	0.043***
	(0.304)	(0.560)	(0.324)	(0.570)	(0.178)	(0.202)	(0.204)	(0.321)	(0.003)	(0.003)	(0.002)	(0.003)
R-squared	0.962	0.966	0.964	0.967	1.000	1.000	1.000	1.000	0.904	0.910	0.905	0.910
Modified Wald	8.5e+04***	3.4e+04***	3.1e+05***	9.9e+03***	-	-	-	-	-	-	-	-
Autocorrelation	52.54***	38.88***	47.51***	36.51***	-	-	-	-	-	-	-	-
Obs.	252	252	229	229	252	252	229	229	189	189	171	171

Notes: (1) Robust standard errors for FE and panel-corrected standard errors for PW are shown in parentheses. For FD, robust standard error, robust heteroscedasticity-consistent standard error, or Newey-West standard error are shown in parentheses, depending on the Wooldridge test for autocorrelation in panel data, Breusch-Pagan test for heteroskedasticity. (2) *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 9: Estimation results: Energy intensity (Industrial sector)

	FE				PW				FD			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
URB	-0.039	0.478**	-0.048	0.409**	-0.039**	0.486***	-0.048***	0.413***	-0.025	0.531***	-0.029	0.463***
	(0.032)	(0.207)	(0.029)	(0.197)	(0.016)	(0.037)	(0.018)	(0.039)	(0.023)	(0.155)	(0.045)	(0.166)
URB × INC	-	-0.074**	-	-0.065**	-	-0.074***	-	-0.065***	-	-0.079***	-	-0.070**
		(0.029)		(0.028)		(0.004)		(0.004)		(0.022)		(0.024)
INC	-1.059***	-0.826***	-1.102***	-0.894***	-1.058***	-0.823***	-1.102***	-0.892***	-1.053***	-0.809***	-1.076***	-0.857***
	(0.060)	(0.112)	(0.058)	(0.106)	(0.026)	(0.027)	(0.043)	(0.044)	(0.037)	(0.080)	(0.040)	(0.085)
IND	-0.931***	-0.962***	-0.943***	-0.969***	-0.931***	-0.964***	-0.943***	-0.970***	-0.959***	-0.978***	-0.970***	-0.985***
	(0.023)	(0.021)	(0.023)	(0.022)	(0.011)	(0.009)	(0.013)	(0.009)	(0.019)	(0.022)	(0.022)	(0.024)
FDI	-	-	0.035	0.035	-	-	0.035*	0.036**	-	-	0.030	0.026
			(0.028)	(0.025)			(0.019)	(0.015)			(0.024)	(0.021)
UNE	-	-	-0.007	-0.009	-	-	-0.007*	-0.009***	-	-	-0.002	-0.004
			(0.006)	(0.006)			(0.004)	(0.003)			(0.005)	(0.004)
HUM	-	-	0.014	0.016	-	-	0.014*	0.016**	-	-	0.005	0.006
			(0.018)	(0.017)			(0.008)	(0.007)			(0.010)	(0.009)
Constant	10.787***	9.268***	11.043***	9.602***	10.794***	9.254***	12.171***	12.918***	0.024***	0.043***	0.027***	0.027***
	(0.490)	(0.806)	(0.470)	(0.756)	(0.231)	(0.198)	(0.387)	(0.400)	(0.003)	(0.005)	(0.004)	(0.003)
R-squared	0.979	0.981	0.981	0.983	1.000	1.000	1.000	1.000	0.952	0.956	0.954	0.957
Modified Wald	1.3e+06***	1.4e+06***	1.5e+06***	7.2e+05***	-	-	-	-	-	-	-	-
Autocorrelation	101.86***	92.23***	96.02***	97.21***	-	-	-	-	-	-	-	-
Obs.	252	252	229	229	252	252	229	229	189	189	171	171

Notes: (1) Robust standard errors for FE and panel-corrected standard errors for PW are shown in parentheses. For FD, robust standard error, robust heteroscedasticity-consistent standard error, or Newey-West standard error are shown in parentheses, depending on the Wooldridge test for autocorrelation in panel data, Breusch-Pagan test for heteroskedasticity. (2) *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 10: Estimation results: Energy intensity (Agricultural sector)

	FE				PW				FD			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
URB	0.115	1.418*	0.105	1.249*	0.116***	1.451***	0.107***	1.279***	0.118	1.827***	0.113	1.724**
	(0.071)	(0.739)	(0.072)	(0.715)	(0.041)	(0.407)	(0.023)	(0.432)	(0.076)	(0.645)	(0.085)	(0.686)
URB × INC	-	-0.185*	-	-0.162	-	-0.190***	-	-0.166***	-	-0.243***	-	-0.229**
		(0.103)		(0.100)		(0.057)		(0.062)		(0.089)		(0.095)
INC	-0.099	0.488	-0.038	0.482	-0.097	0.504***	-0.040	0.492***	-0.058	0.692**	-0.098	0.619*
	(0.300)	(0.403)	(0.321)	(0.385)	(0.098)	(0.145)	(0.121)	(0.123)	(0.183)	(0.305)	(0.208)	(0.324)
IND	0.556***	0.478**	0.563***	0.499**	0.552***	0.472***	0.559***	0.494***	0.435***	0.377**	0.439**	0.391**
	(0.180)	(0.189)	(0.187)	(0.194)	(0.078)	(0.090)	(0.078)	(0.077)	(0.148)	(0.159)	(0.170)	(0.178)
FDI	-	-	-0.188**	-0.186**	-	-	-0.188***	-0.186***	-	-	-0.129	-0.144
			(0.090)	(0.084)			(0.039)	(0.043)			(0.106)	(0.102)
UNE	-	-	0.017	0.012	-	-	0.017***	0.011*	-	-	0.015	0.009
			(0.027)	(0.026)			(0.005)	(0.007)			(0.015)	(0.014)
HUM	-	-	0.107*	0.111*	-	-	0.106***	0.110***	-	-	0.080**	0.081**
			(0.055)	(0.057)			(0.040)	(0.041)			(0.036)	(0.035)
Constant	-6.667***	-10.492***	-7.255***	-10.744***	-8.244***	-12.175***	-7.734***	-12.242***	0.014	0.056***	0.022***	0.022
	(2.172)	(2.773)	(2.266)	(2.580)	(0.587)	(0.852)	(0.915)	(0.815)	(0.015)	(0.018)	(0.017)	(0.022)
R-squared	0.480	0.497	0.495	0.508	0.999	0.999	0.999	0.999	0.180	0.217	0.195	0.226
Modified Wald	5.6e+04***	1.0e+04***	1.3e+04***	6.6e+03***	-	-	-	-	-	-	-	-
Autocorrelation	70.55***	102.48***	55.80***	76.61***	-	-	-	-	-	-	-	-
Obs.	252	252	229	229	252	252	229	229	189	189	171	171

Notes: (1) Robust standard errors for FE and panel-corrected standard errors for PW are shown in parentheses. For FD, robust standard error, robust heteroscedasticity-consistent standard error, or Newey-West standard error are shown in parentheses, depending on the Wooldridge test for autocorrelation in panel data, Breusch-Pagan test for heteroskedasticity. (2) *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 11: Estimation results: Energy intensity (Service sector)

	FE				PW				FD			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
URB	0.003	2.613***	0.014	2.528***	0.000	2.607***	0.008	2.512***	0.027	2.977***	0.032	2.954***
	(0.122)	(0.814)	(0.128)	(0.878)	(0.043)	(0.253)	(0.037)	(0.292)	(0.190)	(0.945)	(0.202)	(1.030)
URB × INC	-	-0.371***	-	-0.357***	-	-0.371***	-	-0.355***	-	-0.420***	-	-0.414***
		(0.110)		(0.119)		(0.033)		(0.038)		(0.129)		(0.141)
INC	-1.129***	0.048	-1.205***	-0.063	-1.119***	0.050	-1.195***	-0.063	-1.347***	-0.052	-1.373***	-0.073
	(0.406)	(0.441)	(0.443)	(0.467)	(0.122)	(0.189)	(0.123)	(0.216)	(0.459)	(0.329)	(0.509)	(0.375)
IND	0.989***	0.832***	1.000***	0.858***	0.985***	0.830***	0.994***	0.854***	1.027***	0.928***	1.032***	0.944***
	(0.227)	(0.199)	(0.234)	(0.201)	(0.050)	(0.078)	(0.051)	(0.088)	(0.293)	(0.231)	(0.303)	(0.238)
FDI	-	-	0.063	0.068	-	-	0.065	0.070	-	-	0.045	0.019
			(0.119)	(0.126)			(0.089)	(0.086)			(0.173)	(0.119)
UNE	-	-	0.004	-0.007	-	-	0.006	-0.006	-	-	-0.004	-0.016
			(0.028)	(0.025)			(0.012)	(0.015)			(0.019)	(0.016)
HUM	-	-	0.022	0.031	-	-	0.030	0.036	-	-	-0.035	-0.034
			(0.058)	(0.060)			(0.059)	(0.068)			(0.069)	(0.053)
Constant	2.060	-5.602*	2.406	-5.202	0.770	-4.254***	1.186	-3.572**	0.040	0.083***	0.043	0.042
	(2.725)	(3.094)	(2.983)	(3.240)	(0.811)	(1.495)	(0.870)	(1.662)	(0.032)	(0.030)	(0.037)	(0.035)
R-squared	0.490	0.542	0.493	0.539	0.998	0.998	0.998	0.998	0.410	0.459	0.420	0.464
Modified Wald	5.1e+05***	8.2e+06***	1.1e+06***	1.1e+05***	-	-	-	-	-	-	-	-
Autocorrelation	25.52***	20.67***	26.79***	21.73***	-	-	-	-	-	-	-	-
Obs.	252	252	229	229	252	252	229	229	189	189	171	171

Notes: (1) Robust standard errors for FE and panel-corrected standard errors for PW are shown in parentheses. For FD, robust standard error, robust heteroscedasticity-consistent standard error, or Newey-West standard error are shown in parentheses, depending on the Wooldridge test for autocorrelation in panel data, Breusch-Pagan test for heteroskedasticity. (2) *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 12: Estimation results: Emission intensity (Industrial sector)

	FE				PW				FD			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
URB	-0.026	0.390***	-0.032	0.303**	-0.025**	0.386***	-0.031***	0.304***	-0.020	0.365***	-0.023	0.309***
	(0.030)	(0.147)	(0.028)	(0.147)	(0.011)	(0.034)	(0.011)	(0.044)	(0.018)	(0.102)	(0.018)	(0.088)
URB × INC	-	-0.059***	-	-0.048**	-	-0.058***	-	-0.048***	-	-0.055***	-	-0.047***
		(0.021)		(0.021)		(0.006)		(0.007)		(0.014)		(0.012)
INC	-1.061***	-0.874***	-1.070***	-0.917***	-1.056***	-0.871***	-1.064***	-0.911***	-1.029***	-0.860***	-1.033***	-0.885***
	(0.035)	(0.076)	(0.037)	(0.074)	(0.020)	(0.022)	(0.026)	(0.038)	(0.019)	(0.049)	(0.020)	(0.044)
IND	-0.962***	-0.987***	-0.971***	-0.990***	-0.965***	-0.988***	-0.973***	-0.991***	-0.979***	-0.992***	-0.984***	-0.994***
	(0.017)	(0.014)	(0.018)	(0.016)	(0.010)	(0.007)	(0.011)	(0.008)	(0.011)	(0.011)	(0.012)	(0.012)
FDI	-	-	-0.000	0.000	-	-	-0.000	-0.001	-	-	-0.007	-0.010
			(0.017)	(0.015)			(0.013)	(0.011)			(0.019)	(0.018)
UNE	-	-	0.002	0.001	-	-	0.002	0.000	-	-	0.001	-0.001
			(0.003)	(0.003)			(0.002)	(0.001)			(0.002)	(0.002)
HUM	-	-	-0.011	-0.009	-	-	-0.009	-0.008	-	-	-0.002	-0.002
			(0.013)	(0.014)			(0.006)	(0.005)			(0.005)	(0.005)
Constant	11.045***	9.824***	11.018***	9.924***	13.401***	12.613***	13.546***	12.929***	0.049***	0.037***	0.050***	0.050***
	(0.294)	(0.539)	(0.307)	(0.529)	(0.164)	(0.158)	(0.216)	(0.269)	(0.002)	(0.002)	(0.002)	(0.002)
R-squared	0.988	0.990	0.990	0.991	1.000	1.000	1.000	1.000	0.981	0.983	0.983	0.984
Modified Wald	6.6e+05***	1.3e+05***	2.2e+05***	7.3e+04***	-	-	-	-	-	-	-	-
Autocorrelation	90.10***	71.11***	66.71***	59.64***	-	-	-	-	-	-	-	-
Obs.	252	252	229	229	252	252	229	229	189	189	171	171

Notes: (1) Robust standard errors for FE and panel-corrected standard errors for PW are shown in parentheses. For FD, robust standard error, robust heteroscedasticity-consistent standard error, or Newey-West standard error are shown in parentheses, depending on the Wooldridge test for autocorrelation in panel data, Breusch-Pagan test for heteroskedasticity. (2) *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 13: Estimation results: Emission intensity (Agricultural sector)

	FE				PW				FD			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
URB	0.092**	-0.312	0.083**	-0.281	0.090***	-0.290	0.082***	-0.273	0.071***	-0.157	0.067**	-0.101
	(0.040)	(0.390)	(0.039)	(0.375)	(0.025)	(0.179)	(0.019)	(0.222)	(0.026)	(0.427)	(0.030)	(0.448)
URB × INC	-	0.057	-	0.052	-	0.054**	-	0.050	-	0.032	-	0.024
		(0.053)		(0.051)		(0.027)		(0.032)		(0.060)		(0.062)
INC	-0.212	-0.394	-0.129	-0.294	-0.207***	-0.379***	-0.129	-0.290***	-0.142	-0.242	-0.127	-0.202
	(0.188)	(0.250)	(0.181)	(0.230)	(0.077)	(0.087)	(0.079)	(0.060)	(0.138)	(0.223)	(0.134)	(0.225)
IND	0.210**	0.234**	0.201**	0.222**	0.208**	0.231***	0.202***	0.221***	0.179*	0.187*	0.184*	0.188*
	(0.101)	(0.102)	(0.101)	(0.101)	(0.054)	(0.050)	(0.074)	(0.065)	(0.102)	(0.103)	(0.105)	(0.106)
FDI	-	-	-0.096**	-0.096**	-	-	-0.096***	-0.097***	-	-	-0.095*	-0.093*
			(0.043)	(0.045)			(0.022)	(0.019)			(0.053)	(0.053)
UNE	-	-	0.018*	0.020**	-	-	0.018***	0.019***	-	-	0.013*	0.014**
			(0.009)	(0.009)			(0.004)	(0.005)			(0.006)	(0.007)
HUM	-	-	0.023	0.021	-	-	0.023	0.022	-	-	0.036*	0.036*
			(0.033)	(0.030)			(0.020)	(0.020)			(0.020)	(0.020)
Constant	-4.422***	-3.239*	-5.054***	-3.963**	-3.730***	-4.052***	-4.349***	-1.703***	-0.024**	0.016	-0.023**	-0.023*
	(1.256)	(1.675)	(1.246)	(1.565)	(0.485)	(0.535)	(0.494)	(0.441)	(0.010)	(0.010)	(0.011)	(0.013)
R-squared	0.228	0.237	0.266	0.273	1.000	1.000	1.000	1.000	0.331	0.332	0.344	0.345
Modified Wald	3.5e+04***	7.3e+04***	1.2e+05***	4.0e+05***	-	-	-	-	-	-	-	-
Autocorrelation	37.59***	35.78***	37.80***	36.19***	-	-	-	-	-	-	-	-
Obs.	252	252	229	229	252	252	229	229	189	189	171	171

Notes: (1) Robust standard errors for FE and panel-corrected standard errors for PW are shown in parentheses. For FD, robust standard error, robust heteroscedasticity-consistent standard error, or Newey-West standard error are shown in parentheses, depending on the Wooldridge test for autocorrelation in panel data, Breusch-Pagan test for heteroskedasticity. (2) *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 14: Estimation results: Emission intensity (Service sector)

	FE				PW				FD			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
URB	-0.020	0.884	-0.009	0.998	-0.020	0.880***	-0.008	0.996***	-0.021	0.993	-0.014	1.129
	(0.105)	(0.698)	(0.106)	(0.767)	(0.030)	(0.150)	(0.031)	(0.151)	(0.063)	(0.962)	(0.060)	(1.041)
URB × INC	-	-0.129	-	-0.143	-	-0.128***	-	-0.143***	-	-0.144	-	-0.162
		(0.092)		(0.101)		(0.021)		(0.020)		(0.131)		(0.142)
INC	-1.242***	-0.834***	-1.295***	-0.838**	-1.248***	-0.847***	-1.297***	-0.842***	-1.432***	-0.987***	-1.402***	-0.893***
	(0.311)	(0.309)	(0.340)	(0.336)	(0.123)	(0.170)	(0.119)	(0.185)	(0.380)	(0.265)	(0.395)	(0.305)
IND	0.642***	0.588***	0.638***	0.582***	0.648***	0.598***	0.642***	0.587***	0.772***	0.738***	0.776***	0.742***
	(0.237)	(0.211)	(0.237)	(0.209)	(0.063)	(0.072)	(0.074)	(0.088)	(0.286)	(0.258)	(0.292)	(0.263)
FDI	-	-	0.156	0.158	-	-	0.155*	0.156*	-	-	0.079	0.069
			(0.106)	(0.112)			(0.086)	(0.083)			(0.089)	(0.086)
UNE	-	-	0.006	0.001	-	-	0.005	0.000	-	-	-0.006	-0.011
			(0.015)	(0.014)			(0.011)	(0.012)			(0.011)	(0.010)
HUM	-	-	-0.062	-0.058	-	-	-0.063	-0.060	-	-	-0.080*	-0.080*
			(0.038)	(0.042)			(0.049)	(0.052)			(0.043)	(0.043)
Constant	1.508	-1.145	1.937	-1.090	1.600***	6.017***	9.028***	8.252***	0.003	0.043	-0.003	-0.003
	(1.892)	(2.354)	(2.079)	(2.529)	(0.889)	(1.083)	(0.816)	(1.507)	(0.025)	(0.026)	(0.027)	(0.027)
R-squared	0.778	0.782	0.780	0.785	1.000	1.000	1.000	1.000	0.464	0.472	0.469	0.478
Modified Wald	3.5e+06***	2.6e+06***	2.2e+05***	5.5e+08***	-	-	-	-	-	-	-	-
Autocorrelation	45.43***	39.22***	54.79***	44.93***	-	-	-	-	-	-	-	-
Obs.	252	252	229	229	252	252	229	229	189	189	171	171

Notes: (1) Robust standard errors for FE and panel-corrected standard errors for PW are shown in parentheses. For FD, robust standard error, robust heteroscedasticity-consistent standard error, or Newey-West standard error are shown in parentheses, depending on the Wooldridge test for autocorrelation in panel data, Breusch-Pagan test for heteroskedasticity. (2) *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 15: Estimation results: Seemingly unrelated regression

	Whole economy		Industrial sector		Agriculture sector		Service sector	
	Energy intensity	Emission intensity	Energy intensity	Emission intensity	Energy intensity	Emission intensity	Energy intensity	Emission intensity
URB	0.879***	0.356***	0.409***	0.303***	1.249***	-0.281	2.528***	0.998**
	(0.191)	(0.085)	(0.108)	(0.072)	(0.478)	(0.243)	(0.531)	(0.442)
URB × INC	-0.131***	-0.055***	-0.065***	-0.048***	-0.162**	0.052	-0.357***	-0.143**
	(0.027)	(0.012)	(0.015)	(0.010)	(0.067)	(0.034)	(0.075)	(0.062)
INC	-0.665***	-0.877***	-0.894***	-0.917***	0.482*	-0.294**	-0.063	-0.838***
	(0.105)	(0.047)	(0.060)	(0.040)	(0.263)	(0.134)	(0.292)	(0.244)
IND	0.117***	0.010	-0.969***	-0.990***	0.499***	0.222***	0.858***	0.582***
	(0.033)	(0.015)	(0.019)	(0.012)	(0.083)	(0.042)	(0.092)	(0.076)
FDI	0.045	0.002	0.035*	0.000	-0.186**	-0.096**	0.068	0.158**
	(0.034)	(0.015)	(0.020)	(0.013)	(0.086)	(0.044)	(0.096)	(0.080)
UNE	-0.016**	-0.002	-0.009**	0.001	0.012	0.020**	-0.007	0.001
	(0.007)	(0.003)	(0.004)	(0.003)	(0.018)	(0.009)	(0.020)	(0.017)
HUM	0.049**	-0.009	0.016	-0.009	0.111**	0.021	0.031	-0.058
	(0.021)	(0.009)	(0.012)	(0.008)	(0.053)	(0.027)	(0.059)	(0.049)
Obs.	229	229	229	229	229	229	229	229

Notes: *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 16: Energy and emission intensity elasticities of urbanization

	Average income province	Highest income province	Lowest income province
Energy intensity elasticities			
Whole economy	-0.042	-0.312	0.074
Industrial	-0.045	-0.177	0.011
Agriculture	0.109	-0.228	0.253
Service	0.009	-0.711	0.318
Emission intensity elasticities			
Whole economy	-0.032	-0.141	0.015
Industrial	-0.034	-0.132	0.007
Agriculture	0.082	-	-
Service	-0.012	-0.302	0.112

Notes: (1) Columns of average income, lowest income, and highest income provinces show elasticities for provinces with the average, the lowest, and the highest level of provincial GDP per capita over all provinces in 2013. (2) The calculation is based on the results of Model 4 of the PW estimation, except that the result of Model 3 of the PW estimation for emission intensity elasticity in the agriculture sector.