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Excessive electricity intensity of Vietnam: Evidence from a comparative study of Asia-Pacific countries

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ABSTRACT

As electricity consumption in Vietnam has continued to increase much faster than has GDP, electricity intensity (*EI*) in the country has risen to levels far exceeding those of other Asia-Pacific economies (APEs). By analyzing evidence from a comparative study of other APEs through using the World Bank data, this study proves that *EI* in Vietnam is excessive and that its escalation over the last few decades cannot be justified as being due to supporting the country's policy of high economic growth. Factor analysis of the economic and electricity indicators for 22 APEs was used to track the shortcomings of the economic structure leading to the *EI* escalation in Vietnam. Electricity tariff, service share of GDP, and level of institution were identified as determinants of *EI* across the region. Given the weak performance regarding these indicators, Vietnam has highest *EI* among APEs followed by China and Mongolia. To reduce *EI*, Vietnam should consider diversifying away from the electricity-intensive industry sector toward economic activities such as service and information technology. The economic reform should be accelerated to complete the competitive electricity market and reduce the inefficiency of electricity usage through poorly managed state-owned enterprises and inefficient public investment projects.

1. Introduction

The power sector in Vietnam has expanded rapidly. Between 1995 and 2014, electricity consumption (EC) grew 11.3-fold, surpassing substantially the 1.4-fold global growth (WB, 2015). Although approximately 50% of Vietnam's population had no access to electricity in 1995, by 2014, more than 99% of communes and 97% of households had been connected to the power grid (Asian Development Bank, 2015). Additionally, losses in power transmission and the distribution system decreased from 15% to 9% over the same period.

Since the adoption of the economic renovation policies known as “Doi Moi” in the late 1980's and after the collapse of the Soviet system, Vietnam has shifted from a centrally-planned to an open, market-oriented, and globally integrated economy. The 1992 Amended Constitution recognized the role of the private sector. Inflows of foreign direct investment (FDI) have facilitated the development of Vietnam's key export-oriented manufacturing industries. The private and FDI sectors have played an important role in boosting the economic growth that transformed Vietnam from one of the world's poorest countries to becoming a lower middle-income economy in 2010. Due to the expansion of industrial activities in both domestic (state-owned and private) and FDI sectors, as well as the growing household demand for electricity, EC has increased rapidly. Because of this increase of EC, electricity intensity (*EI*), measured as the EC per unit of gross domestic product (GDP), has soared steadily, nearly fourfold, from 1995 to 2014 making Vietnam the most electricity-intensive economy in the Asia-Pacific region.

As a consequence of its rapidly growing power consumption, Vietnam has been experiencing a shortage of domestic energy resources and must rely increasingly on importing electricity, oil, and steam coal, thus raising issues of energy supply security (WB, 2010). To address this challenge, the Seventh National Master Plan for Power Development (PDP-7) for the 2011–2020 period sets out a specific target to reduce the electricity elasticity (*EE*) defined as the ratio between the EC growth rate and the growth rate of GDP in the same period from approximately 2 in 2011, to 1.5 in 2015, and 1 in 2020 (Prime Minister of Vietnam, 2011). This roadmap was part of the National Energy Efficient Program (NEEP), which focused on the activities and mandatory measures that promote efficient energy use across Vietnam.

However, the performance of the electricity sector fell far short of achieving the PDP-7 goals; instead, EC increased approximately twice as fast as did GDP. This increase indicated a highly inefficient use of electricity through channels outside the scope of the NEEP, which targeted mainly the technical aspects of energy conservation on the supply and demand sides. Hence it is imperative to track these shortcomings of the economic structure and policies to develop measures to reverse the escalation of *EI*.

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Abbreviations

ADB	Asian Development Bank
APE	Asia-Pacific economies
AUS	Australia
BGD	Bangladesh
BRN	Brunei Darussalam
CHN	China
EC	Electricity consumption
EE	Electricity elasticity
EI	Electricity intensity
EP	Electricity productivity
FDI	Foreign direct investment
GDP	Gross Domestic Product
GSO	General Statistics Office of Vietnam
HKG	Hong Kong
IND	India
IDN	Indonesia
JPN	Japan
KOR	Korea
MYS	Malaysia
LKA	Sri Lanka
MNG	Mongolia
NEEP	National Energy Efficient Program
pc	per capita
NPL	Nepal
NZL	New Zealand
OECD	Organisation for Economic Co-operation and Development
PAK	Pakistan
PDP-7	Vietnam's Seventh Power Development Master Plan
PHL	Philippines
SGP	Singapore
SOE	State-owned enterprise
THA	Thailand
VNM	Vietnam
WB	World Bank
WEF	World Economic Forum

For this purpose, this paper examines *EI* and related economic indicators of Vietnam in a comparative study of 22 Asia Pacific Economies (APEs). The combined population, GDP, and EC of APEs account for 53%, 41%, and 30% of the total world's population, GDP, and EC respectively. Meanwhile, the diversity of APEs regarding development stages, economic structures, natural resource endowments, and political regimes creates a complete view of electricity use for economic development to reveal the unusual case of Vietnam. Based on empirical evidence deduced from the variations of *EI* over time and across APEs, which are among the fastest-growing economies in the world, this study proves that *EI* in Vietnam is excessive and that its escalation over the last few decades cannot be justified as being necessary to support the policy of high economic growth. Furthermore, factor analysis of the macroeconomic and electricity indicators from 22 APEs was used to reveal the indicators that underlie the *EI* variations across the region and hence are responsible for the high *EI* in Vietnam.

As shown by many researchers, comparative studies of *EI* temporal and cross-country variation patterns are robust in providing insights into the energy efficiency policy and economic structure of countries. In investigating the *EI* and electricity demand in the different US states from the 1970s to 2003, Horowitz (2007) found that those states that have moderate to strong commitment to energy efficiency programs exhibit reduced *EI* relative to what it would have been with weak program commitment. From a cross-country study of the temporal patterns of *EI* from 1960 to 2005 in 22 OECD countries, Liddle (2009) found they converged toward a common mean, reflecting the situation of highly developed countries having similar economic and social scheme.

The remainder of this paper is organized as follows. Section 2 describes the fast growing EC in Vietnam. The economic and electricity profiles of APEs and the methodology used in this comparative study are described in section 3. In section 4 the cross-country and time series *EI* - pc GDP relationships in the last four decades in APEs are examined to provide evidence for the excessive *EI* of Vietnam. Factor analysis of economic and electricity indicators in APEs is presented in section 5. The empirical findings from factor analysis and policy implications are discussed in section 6. Section 7 concludes the paper.

2. Electricity usage in Vietnam

Between 1995 and 2014, EC in Vietnam increased from 11.5 billion kWh to 130 billion kWh (Fig. 1), corresponding to an annual average growth rate of 13.6%, twice that of the country's GDP (6.8%).

Pc EC has grown at an average annual rate of 12%, from 159.3 kWh in 1995 to 1,389 kWh in 2014, reflecting both major improvements in electrification rates and rising incomes (Asian Development Bank,

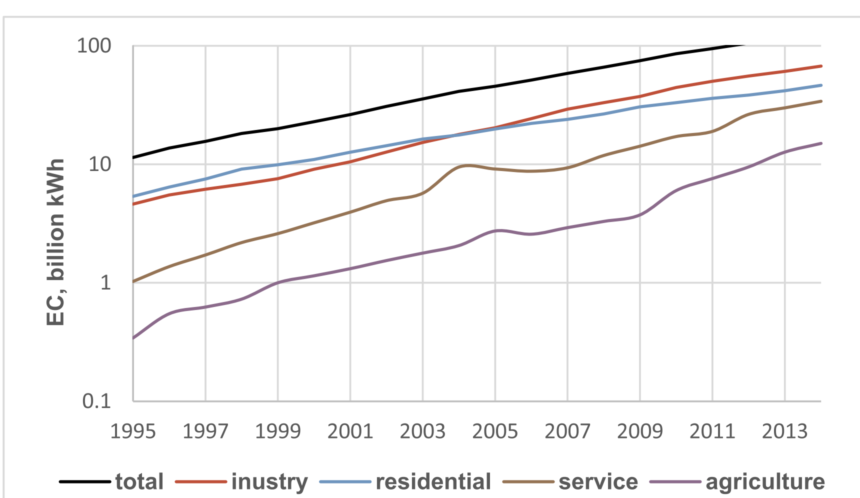

Fig. 1. Total and sectorial EC in Vietnam, 1995–2014 (Asian Development Bank (2015).

2015). The residential and industry sectors have been the largest consumers, but industry consumption has increased faster, at 16% per year, outperforming residential consumption since 2004 (Fig. 1). In 2014, industry accounted for 53% of the total consumption, whereas the consumption figures for the residential, service, and agriculture sectors for 2014 are 30%, 26%, and 11%, respectively.

However, as the electricity growth rate has consistently doubled the GDP growth rate over the past few decades (*EE* ~ 2), *EI* increased rapidly (section 4), reaching 0.94 kWh/US$ in 2014 (Fig. 2). As a result, Vietnam is among the world's top electricity-intensive economies, along with the five former Soviet republics in Central Asia and Eastern Europe, and it is the most electricity-intensive economy in the Asia-Pacific region (WB, 2015). Industry is the most electricity-intensive sector in the Vietnam economy. The *EI*, calculated by dividing the EC in industry by the industry value added in GDP, increased from 0.39 kWh/US$ in 1995 to 1.3 kWh/US$ in 2014, which is much faster than was the growth of *EI* in the agriculture sector, the service sector, and the whole economy (Fig. 2).

The fast-growing demand for power in industry in Vietnam largely reflects the policy of export-oriented industrialization as the key driver of the country's rapid growth (Asian Development Bank, 2015). This policy is laid out clearly in the National Five-Year Plans and it has been vital as the country is becoming more open and more deeply integrated with the world economies, notably since it became a member of the World Trade Organisation membership in 2007. Manufacturing and processing activities accounted for 81 to 86 per cent of the Vietnam's industrial production outputs in 2000–2010, and the export value reached 70.6 per cent of GDP by 2010 (GSO, 2011). However, Vietnam has been struggling with many issues regarding the low productivity of the economy and the inefficiency of using resources and energy for industrial development (WB, 2010; WB, 2012; Solidiance, 2015). The comparative analysis of the economic performance and electricity usage in 22 APEs will shed light on the reasons behind the highly inefficient use of electricity in Vietnam.

3. Data and research methodology

In this study, the annual data for real pc GDP, GDP components, labor productivity, and electricity performance indicators of the APEs were obtained from the World Development Indicators (WB, 2015) and Global Competitiveness Reports of the World Economic Forum (2014). The real pc GDP is given in US$ at constant 2010 prices. Table 1 presents the relevant economic and electricity characteristics of the 22 APEs' studied. Data on other characteristics that are used as input variables for factor analysis (section 5) are given in the Appendix. Some of these data come from additional sources indicated in section 5. Several APEs were not included in this comparative study due to incomplete data for the studied period (North Korea, Myanmar, and Bhutan) or lack of data in the Global Competitiveness Reports (Papua New Guinea and Fiji).

The research methodology adopted in the comparative study is as follows. A simple comparison of the *EIs* of APEs in 1995 and 2014 indicates that the behavior of *EI* depends on the country's level of development. Hence, pc GDP is chosen as a proxy for economic development and the relationship between *EI* and pc GDP for APEs are examined by cross-country and time series analyses. The excessive *EI* of Vietnam is uncovered easily on the cross-country *EI*-pc GDP plot. Meanwhile, the unusual pathway of electricity usage leading to the excessive *EI* of Vietnam can be revealed by examining the time series *EI*-pc GDP relationships for APEs. These time series relationships cover the period from 1975 to 2014, which is long enough for many developing countries in the region to proceed through the various stages of development.

Table 1
Economic and electricity profiles of APEs in 2014 (WB, 2015).

Country	pc GDP (2010 US$)	Industry value added (% GDP)	Service value added (% GDP)	pc EC (kWh)	Population (million)
Australia	54,294	20	78	10,059	23.5
Bangladesh	922	28	53	310	158
Brunei	33,314	25	74	10,243	0.41
Cambodia	973	26	41	271	15
China	6,198	47	43	3,927	1,364
Hong Kong	35,717	7	93	6,083	7.2
India	1,646	26	55	805	1296
Indonesia	3,693	38	47	812	251
Japan	46,484	27	72	7,820	127
Korea	36,259	39	58	10,496	50
Laos	1,470	30	37	353	6.8
Malaysia	10,398	44	45	4,596	30
Mongolia	3,901	38	46	2,017	2.9
Nepal	676	15	48	139	27
N. Zealand	36,006	25	66	9,026	4.3
Pakistan	1,111	25	53	471	194
Philippines	2,506	33	55	699	97.6
Singapore	51,865	28	72	8,845	5.5
Sri Lanka	3,507	29	58	531	21
Taiwan	22,716	40	60	10,368	23.4
Thailand	5,590	45	43	2,540	67
Vietnam	1,565	41	38	1,411	91
Average	16,401	31	56	4,174	176
Std. deviation	19,061	10	15	4,083	380

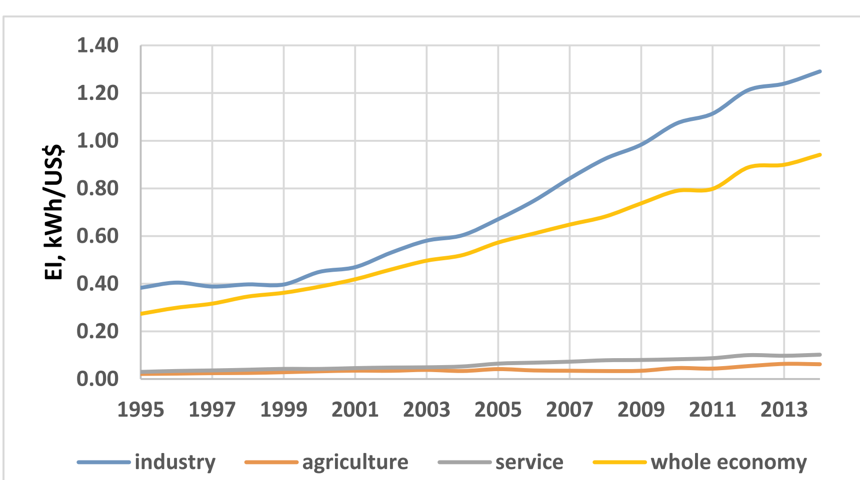

Fig. 2. Time series of aggregate and sectorial *EI* in Vietnam, 1995–2014 (Asian Development Bank, 2015).

To identify the reason for the excessive *EI* of Vietnam, the scope of this comparative analysis is expanded to include nine development indicators of economic activities and electricity usage in APEs. These indicators are correlated with each other and exploratory factor analysis is applied to extract the common factors underlying their interrelationships. The structure of these common factors will show, among other things, the indicators that are driving the *EI* variations across the region and are, hence, responsible for the high *EI* of Vietnam. The factor scores will show the ranking of APEs in terms of *EI,* with Vietnam being the highest. The findings from factor analysis are justified through economic development characteristics and examples of inefficient electricity usage in Vietnam.

4. Comparative analysis of APEs

4.1. Changes of EI in the Asia-Pacific region

With its *EI* increasing by nearly fourfold from 1995 to 2014, Vietnam became the most electricity-intensive economy in the Asia-Pacific region. Such a rapid *EI* escalation did not occur elsewhere in the region, as shown in Fig. 3, in which *EIs* of 19 APEs in 1995 and 2014 are compared. *EI* has increased moderately in most developing countries, but it has decreased in the developed economies (i.e., Japan, Singapore, Australia, New Zealand, and Hong Kong) and also in Mongolia and India.

The reason for the escalation of *EI* in Vietnam has been the substantially high and persistent *EE* throughout the years in recent decades. This relationship between *EE* and the annual growth of *EI* is shown in formula (1), which is derived from the definitions of *EI* in (2) and *EE* in (3)

$$\frac{\Delta EI_i}{EI_i} = \frac{\Delta P_i}{P_i}(EE_i - 1) \tag{1}$$

$$EI_i = \frac{C_i}{P_i} \tag{2}$$

$$EE_i = \frac{\Delta C_i / C_i}{\Delta P_i / P_i} \tag{3}$$

where C_i and P_i are pc EC and pc GDP in year *i*, respectively, and Δ stands for the annual growth operator. According to (1), in the case of economic growth, $\frac{\Delta P_i}{P_i} > 0$, EI_i declines if $EE_i < 1$ (i.e., EC increases more slowly than does GDP) and increases if $EE_i > 1$ (i.e., EC increases faster than does GDP).

Fig. 4 compares the *EE* in Vietnam, China, South Korea, India, and Singapore from 1994 to 2014. The *EE* of Singapore is lowest and mostly below 1, which has caused *EI* to decline over the last two decades (Fig. 3). *EI* of India has also declined since *EE* was below unity in 14 of 24 years.

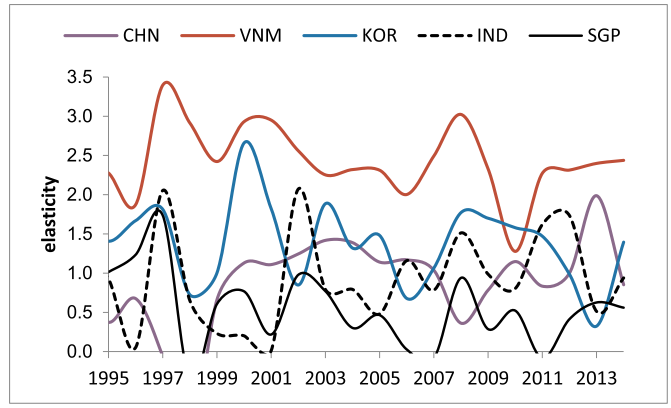

Fig. 4. *EE* in Vietnam, China, South Korea, India, and Singapore, 1995–2014. *EE* is calculated from WB data (WB, 2015).

High *EEs* explain the increase of *EI* in South Korea and China. In Vietnam, *EE* was greater than 2 in most years in the study period, resulting in the fast escalation of *EI* from 1995 to 2014 (Fig. 3).

4.2. EI-pc GDP cross-country relationship

The above findings suggest that, across the region, the behavior of *EI* depends on the country's level of economic development. The cross-country *EI*-pc *GDP* scatter plot in Fig. 5 shows that *EIs* in APEs are distributed around an inverted-U curve, with Nepal, Bangladesh, Pakistan, and India on the upward sloping side and the developed countries (i.e., South Korea, Brunei, New Zealand, Hong Kong, Singapore, Japan, and Australia) on the downward sloping side. On the top base side are middle-income APEs: China, Mongolia, Thailand, and Malaysia. With relatively low *EIs*, the Philippines, Indonesia, and Sri Lanka are satisfactory performers regarding electricity conservation in the region. By contrast, with an *EI* that is much greater than are those of its regional partners, Vietnam is an outlier from the regional trend. The *EIs* of the two other transition economies, China and Mongolia, are also higher than are those of its regional counterparts, but they lower than is that of Vietnam.

A common trend across the Asia-Pacific region is the increasing *EI* with pc *GDP* for countries in the early stage of economic development; however, beyond a certain level of development - an inverted-U turning

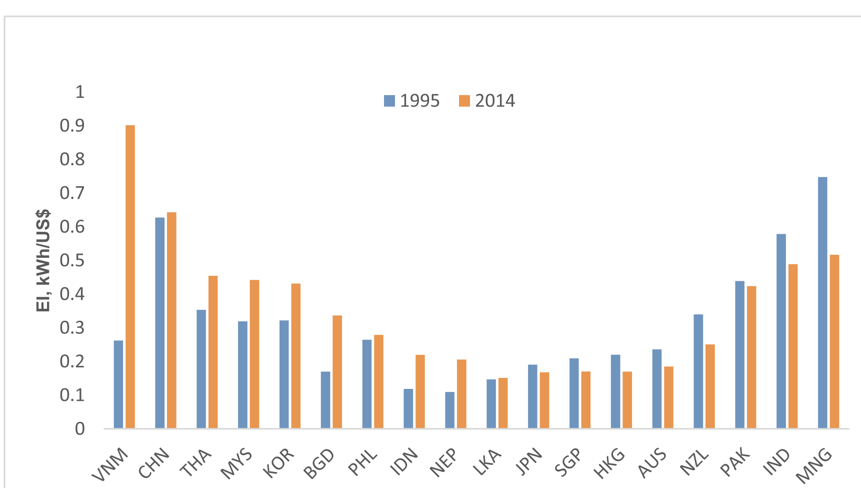

Fig. 3. Changes of *EI* in the Asia-Pacific from 1995 to 2014 (WB, 2015).

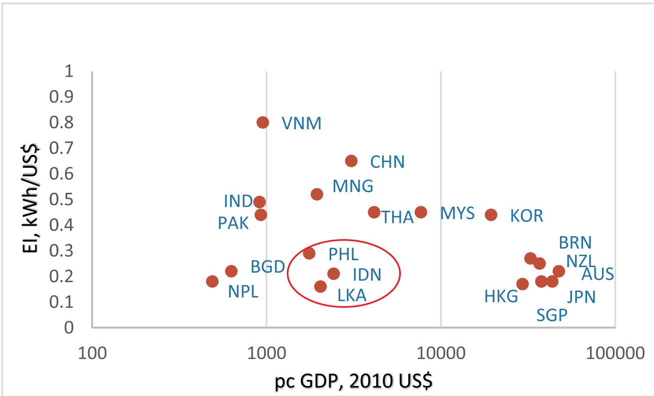

Fig. 5. *EI* versus pc GDP for APEs averaged over the 2009–2013 period.

point - *EI* tends to fall as pc *GDP* continues to increase. As a result, low *EIs* are observed in most developed countries, some as low as in the least developed countries, despite their pc ECs being approximately two orders of magnitude greater. This type of relationship is often referred to as the inverted-U curve, which was advanced by Simon Kuznets to describe the long-run effect of economic growth on income inequality (Kuznets, 1955) and was then applied to other areas, such as environmental pollution (Selden and Song, 1994; Grossman and Krueger, 1995), energy consumption, and CO_2 emissions (Richmond and Kaufmann, 2006; Chima, 2007).

4.3. Time series EI-pc GDP relationships

This section examines whether the inverted-U curve holds for the time series *EI*-pc *GDP* relationship for each APE. Fig. 6 shows the evolution of annual *EI* versus pc *GDP* for 17 APEs from 1975 to 2014. Although the years are not shown explicitly on the horizontal axis, Fig. 6 also represents the time series of the *EI* in each economy.

The inverted-U turning points have occurred in several APEs, such as New Zealand in 1991 when its pc GDP reached 19,814 US$; Australia (1992, 34,968 US$); India (1997, 500 US$); Singapore (1998, 29,641 US$); Philippines (2003, 1100 US$); and Sri Lanka (2005, 2132 US$). Meanwhile, *EI* has been increasing from 1975 to 2014 in Nepal, Bangladesh, and Vietnam, indicating that these relatively low income economies continue to proceed on the upward sloping segments of the inverted-U curves. A turning point was not observed either in Korea or in the higher middle-income countries of Thailand and Malaysia.

It is worth comparing the *EIs* of the three transition economies China, Mongolia and Vietnam. In China, *EI* started to decrease going from 0.82 kWh/US$ in 1979 to 0.56 kWh/US$ in 2000, but it climbed slightly as the country experienced two-digit GDP growth rates in 2002–2010 and has held at 0.65 kWh/US$ since 2008. In Mongolia, *EI* decreased from 0.88 kWh/US$ in 1985 to 0.52 kWh/US$ in 2014. By contrast, over the same period, the *EI* of Vietnam increased steadily from 0.18 to 0.90 kWh/US$, and the *EI* of Vietnam's industry sector increased even faster, going from 0.40 to 1.3 kWh/US$ (Fig. 2).

Thus, the evolution of *EI* with pc GDP in each APE supports the inverted-U Kuznets hypothesis. *EI* increased in the initial phase of development in each APE, but after reaching a certain level of development, it declined as the pc GDP continued to increase. This latter phase represents the condition for sustainable growth with GDP increasing faster than EC, that is, $EE < 1$, according to (1). The increase of *EI* with pc GDP in the early stage of development is due largely to the expansion of electrification. Factors influencing the decline of *EI* with pc GDP in industrialized countries may include a structural shift and technological change toward less electricity-intensive economic activities such as service and information technology, in addition to institutional and market reforms aimed at liberalizing enterprise ownership and electricity prices (Chima, 2007).

4.4. EI escalation in Vietnam and energy policy implications

The *EI* of Vietnam had been low and on par with those of less developed countries three decades ago (0.18 kWh/US$ in 1985) but quickly increased to overtake China in 2008 and then escalated further, leaving all its regional partners far behind (Fig. 6). This phenomenon was a consequence of maintaining a very high *EE* throughout the years (Fig. 4). Contrary to the PDP-7 goals (Prime Minister of Vietnam, 2011), EC in Vietnam is expected to increase annually at 11% from 2016 to 2020, and 7–8% from 2020 to 2030 so that *EE* will remain greater than 1 and a U-turning point is not expected to occur until 2030 at the earliest.

Concern over the threat of impeding economic growth by reducing EC may have hampered both the search for the impetus behind the high *EE* in Vietnam and bold reforms of the electricity sector. The comparative analysis in this work provides empirical evidence disproving such a concern. Many developing APEs with similar income levels and with much lower *EEs* and *EIs* can achieve high GDP growth rates, namely, China (9.5%), India (6.7%), Laos (6.8%), and Malaysia (6.1%), whereas the figure is 6.7% in Vietnam (WB, 2015).

It is worth noting that empirical findings from the studies of the causal relationship between pc EC and pc GDP also justify the energy conservation policy. The policy implications from these studies depend upon the kind of causal relationship that exists. If unidirectional causality running from EC to economic growth is found, policy makers

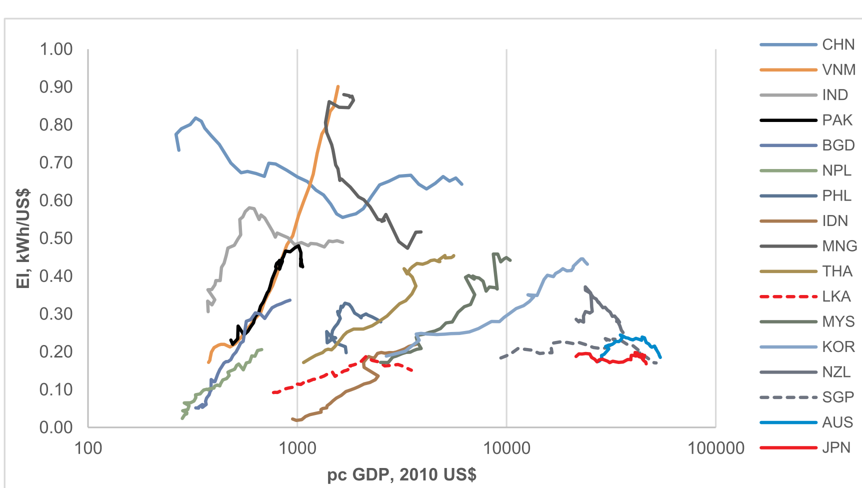

Fig. 6. *EI* as a function of pc GDP from 1975 to 2014 in 17 APEs. (*EI* is calculated from WB data (WB, 2015).

should pay special attention to restrictions of electricity use because this action may impede economic growth (Chen et al., 2007; Ozturk, 2010; Binh, 2011). This is not the case in Vietnam. Using co-integration and Granger causality analysis of time series annual data for the 1975–2010 period, Canh (2011) found significant unidirectional causality running from pc GDP to pc EC, but not vice versa. Binh (2011) also found unidirectional causality running from pc GDP to pc energy consumption. These empirical findings imply that energy/electricity conservation policies may be implemented in Vietnam without having adverse effects on economic growth.

Chen et al. (2007) investigate the causal relationships between GDP and EC in a panel data set from ten newly industrializing and developing APEs, among which China, India, Korea, Malaysia, and Thailand may have a problem of inefficiency of electricity usage, as shown by their high EIs. The authors found a unidirectional short-run causal relationship from GDP to EC and concluded that electricity conservation policies aimed at reducing EC can be initiated with no adverse effects on economic growth.

The above analysis of the relationship between *EI* and pc GDP provides evidence for the excessive *EI* of Vietnam. To understand why the *EI* of Vietnam is excessively high compared with its regional counterparts, the relationships between electricity and economic indicators in 22 APEs will be examined using factor analysis.

5. Factor analysis

5.1. Input variables

This section examines the relationships between electricity and economic indicators in 22 APEs to understand why the *EI* of Vietnam is very high compared with its regional counterparts. Factor analysis is used to resolve these intercorrelated observed variables into a smaller set of latent uncorrelated variables, the structures of which help uncover the economic indicators that control the *EI* variability across the region. Each factor extracted is a composite economic and electricity indicator, the meaning of which can be recognized based on the structure of factor loadings.

Nine economic and electricity indicators for 22 APEs were used as input variables in factor analysis.

Five indicators were selected to reflect the facets of economic development relevant to electricity use as follows:

- Real per capita GDP in constant 2010 US$ (PCGDP) representing a country's income level;
- Service value added as percent of GDP (SERVI);
- Labor productivity (LABPR) based on GDP per-worker;
- Average residential electricity tariffs (TARIF); and
- The quality of the institutional environment (INSTI), determined by the legal and administrative framework within which individuals, firms, and governments interact to generate wealth, according to the World Economic Forum (WEF, 2014).

Four indicators were selected to represent a country's electric sector performance as follows:

- pc EC in kWh (PCECO);
- Electrification rate based on the percentage of rural population with access to electricity (ACCES);
- Efficiency of the power transmission and distribution system (TDSEF), i.e., the complement of the electricity loss in the system; and
- Efficiency of EC (EFFIC) based on the percentage change in GDP gained from a 1% change in EC, i.e., the inverse of *EE*.

Data on PCGDP, SERVI, PCECO, ACCES, LAPRO, and TDSEF were taken from the WB's World Development Indicators (WB, 2015). Data on INSTI, given as indexes from 1 to 6, were from the Global Competitiveness Reports of the World Economic Forum (WEF, 2014). Concerning TARIF, data on the average residential electricity prices (US cent/kWh) in 2011 were taken from STATISTA (2018), Asian Development Bank (2015), and Wikipedia Electricity Pricing (2018).

The input variables have significant correlations with each other, ranging from r = 0.30 for TDSEF and SERVI to r = 0.95 for PCECO and PCGDP, which means that the selected economic and electricity indicators are good for factor analysis. Some other indicators having very low correlations with the above input variables could not be selected.

Most of the input variables, except for EFFIC, represent the averages of the annual values of the indicators from 2009 to 2013 (WB, 2015). EFFIC was calculated as the ratio of the percentage changes of pc GDP and pc EC over that period. Positive skewed data on pc GDP, pc EC, and LABPR were log-transformed to obtain better fits with the normal frequency distribution of input data, as required in factor analysis. Input data for the factor analysis are presented in the Appendix.

5.2. Factor model

The factor model assumes that for country i, the observable multivariate p-vector X_i is generated by

$$X_i - \mu = LF_i + \varepsilon_i \quad (4)$$

where μ is a p x 1 vector of observed variable means, L is a p x m matrix of factor loadings, F_i is a m x 1 vector of standardized unobservable variables, termed common factors, and ε_i is a p x 1 vector of errors or unique factors (IHS Global Inc, 2015). Thus, the factor model expresses the p observable variables X_i - μ in terms of m unobservable common factors ($m < p$) F_i, and p unobservable unique factors. The factor loading matrix L links the unobserved common factors to the observed data. The achievement of each country relative to its regional counterparts in terms of that common factor can be determined based on its factor score. Thus, the factor model consists of two components: the matrix of factor loadings and the matrix of factor scores.

The EViews software was used in factor analysis (IHS Global Inc, 2015). The factor model was derived by using the maximum likelihood method for extraction of factors from the matrix of correlations between input variables followed by orthogonal varimax rotation to achieve simple structures of factors for interpretation. Two factors were extracted based on the minimum eigenvalue criterion (Kaiser-Guttman rule) used for selecting the optimal number of extracted factors in Eviews.

Table 2 shows the *10x2* matrix of varimax rotated factor loadings representing the correlations between observed variables and factors. The third column shows the communality (h^2) representing the variance of an input variable that can be explained by the two factors. The total variance explained by the factor model is shown in the bottom row. Thus, the factor model can explain 81.2% of the total variance in the data set, almost 100% of the variance of PCECO and PCGDP, and from 77% to 91% of the variance of LABPR, TARIF, INSTI, and SERVI.

The matrix of standardized factor scores is displayed as bar charts in

Table 2
Matrix of orthogonally varimax rotated factor loadings.

Variable	factor 1	factor 2	Communality h^2
ACESS	0.715	0.227	0.563
EEFIC	0.452	0.678	0.664
INSTI	0.579	0.712	0.842
LABPR	0.773	0.558	0.910
PCECO	0.934	0.357	1.00
PCGDP	0.780	0.615	0.987
SERVIC	0.291	0.829	0.772
TARIF	0.244	0.901	0.872
TDEFF	0.826	0.153	0.706
Total variance explained			0.812

Fig. 7. These scores have been scaled to have a zero mean and standard deviation of 1, meaning that approximately two-thirds of the values are between −1.00 and + 1.00. To facilitate the comparison of country performance, the factor scores have been ranked in ascending order on the vertical axis of the bare charts.

5.3. Interpretation of the factor model

The factors can be interpreted based on the structures of both the rotated factor loadings (Table 2) and factor scores (Fig. 7). The structure of factor loadings in Table 2 shows two distinct clusters of relationships between the nine input variables. PCGDP, LABPR, TDEFF, and ACCES cluster with PCECO on factor 1. EEFIC, TARIF, SERVI, and INSTI are strongly associated with each other in factor 2.

The structure of factor 1 indicates that across the region pc EC moves in tandem with pc income, LABPR, efficiency of the power transmission and distribution system, and electrification rate. Factor 1 represents the achievement of APEs in using electricity for economic development. As factor 1 correlates strongly with PCECO (r = 0.93, Table 2), the score of APE on factor 1 (Fig. 7a) ranks approximately in accordance with the per capita EC that is lowest in Nepal, Cambodia, and Bangladesh and highest in South Korea and Taiwan (Table 1). Notably, Vietnam ranks eleventh on factor 1, three and four positions ahead of Indonesia (eighth) and the Philippines (seventh), respectively, because Indonesians and Filipinos consume less electricity despite having higher incomes (Table 1). Although Hong Kong has a higher per capita EC, it ranks behind Vietnam (tenth) due to the higher loss of electricity in its power transmission and distribution system (13.4% in Hong Kong versus 9% in Vietnam, see Appendix).

In factor 2, the efficiency of electricity usage has a strong bearing on indicators that influence the productivity of using electricity, that is, service value added, electricity tariffs, and quality of institutions. Factor 2 can be treated as a proxy of electricity productivity (*EP*), the inverse of electricity intensity (Galeotti et al., 2010). Thus, the use of electricity is most productive in Hong Kong, a competitive and advanced market economy with 93% of its GDP coming from its service sector. The next three places are taken by Japan, Singapore, and Australia, in succession. Among the developing countries, Sri Lanka is the most electricity-productive, ranking seventeenth on factor 2. Taiwan and Korea, the regional leaders in EC (Fig. 7a) rank tenth and thirteenth in *EP*, respectively (Fig. 7b). Vietnam ranks lowest in *EP* followed by Mongolia and China, consistent with the very high *EIs* of these transition economies shown in Fig. 5.

6. Discussion

According to the factor model derived in section 5, the very low *EP* (very high *EI*) of Vietnam can be explained as a consequence of economic growth policies that rely heavily on the electricity-intensive industry sector while lacking market-based mechanisms and effective institutions to support competitiveness. The following characteristics of the Vietnamese economy need to be addressed to reverse the current *EI* escalation.

- From 1994 to 2014, the industry sector in Vietnam consumed ten times as much electricity as did the service sector (Fig. 2), but it generated less GDP value added (Table 1). The manufacturing and processing sector, which generated 85 per cent of the industrial production outputs, bears the main responsibility for the highly inefficient electricity usage in Vietnam. This weakness may be attributed to outdated technology in the production process (Energy Alliance, 2012).
- However, the lack of substantial incentives, such as market-based electricity prices, to upgrade technology is also a major factor (Energy Alliance, 2012). Electricity tariffs, maintained by government regulations and subsidies, have been kept below cost-recovery levels and set lower for industries than for the service - commerce sector. In 2011, the average household tariff was US cents 6.04/

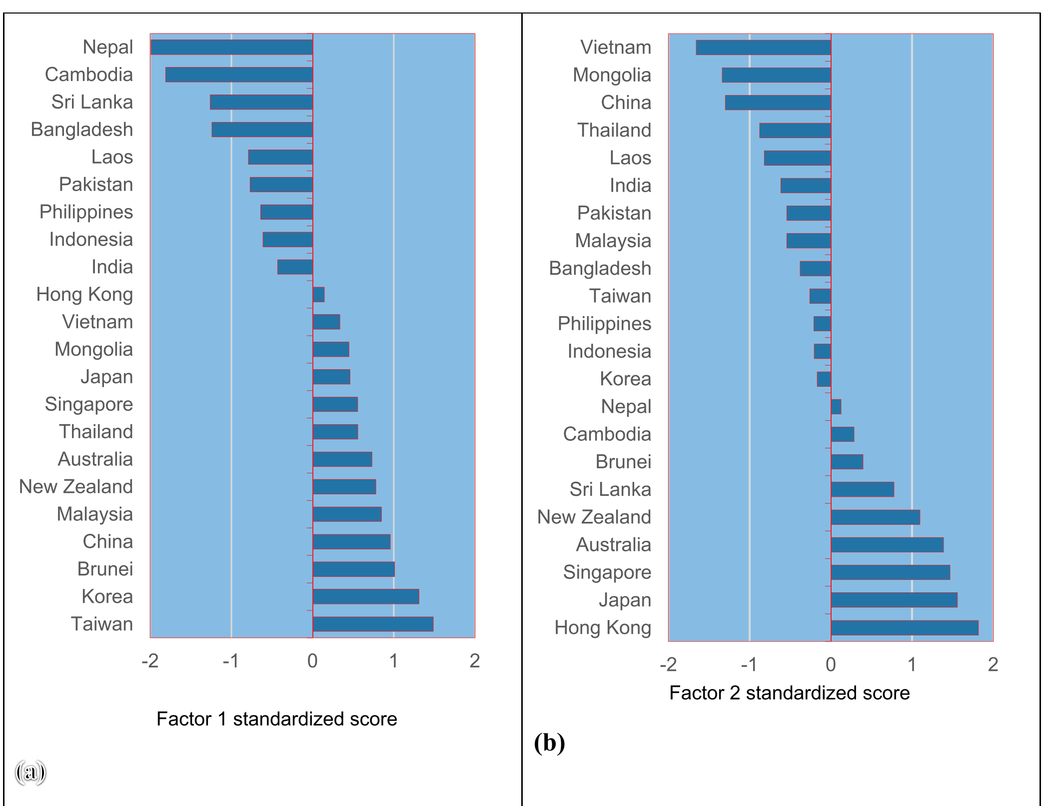

Fig. 7. Standardized scores of APEs on factor 1 (a) and factor 2 (b).

kWh, whereas the long-run marginal cost of the electricity system in Vietnam estimated by Asian Development Bank (2015) was 8–9 US cents/kWh (Asian Development Bank, 2015). The subsidy amount in 2013 was estimated at 1.29 billion US$ equivalent to 0.93 per cent of GDP in the same year (IEA, 2017).

- Cheap electricity prices in Vietnam compared with its neighboring countries (Asian Development Bank, 2015) have encouraged investments in energy-intensive industries, such as steel and cement (Tien and Sharma, 2011; Energy Alliance, 2012) and bauxite mining to extract alumina for export to China (Springer, 2018). As a result, Vietnam has become the largest steel producer in Southeast Asia and the eighth largest cement exporter worldwide. Notably, Vietnam's steel, cement, and alumina producers are highly energy inefficient and uncompetitive compared with their regional counterparts (Energy Alliance, 2012; Thuan, 2015; Springer, 2018).
- The weak institutions leading to the low *EP* of Vietnam are most apparent in state-owned enterprises (SOE), which have privileged access to land and capital but are highly inefficient in using them relative to the domestic private and foreign enterprises (WB, 2012). The fiasco at Vinashin, a huge state-owned shipbuilder, is an expensive lesson for Vietnam's economy. It ran up debt and missed its repayment of a $600 m loan arranged by Credit Suisse for the Vietnam government. The default forced a downgrade of the country's sovereign debt (The Economist, 2013).
- The negative effect of SOEs on electricity use in Vietnam is most apparent in the electricity sector. As long as Electricity of Vietnam and several SOEs under the Ministry of Industry and Trade control the power generation, transmission, and distribution, it will be difficult to establish a healthy competitive electricity market.
- From the demand side, SOEs dominate many electricity-consuming production industries, including fertilizer, coal, oil, water, and cement (WB, 2012). Many SOEs have multimillion-dollar plants that suffer continuing losses and are either left idle or eventually forced to close resulting in wasted energy and electricity (Tuoi tre News, 2016).

7. Conclusion and policy implications

This work demonstrates that across the Asia-Pacific region, the electricity intensity (*EI*) of a country increases with pc *GDP* in the early stage of economic development but, beyond a certain level of development—an inverted-U Kuznets turning point—*EI* tends to fall as pc *GDP* continues to increase. Thus, *EI* has already decreased in developed Asia-Pacific economies (APEs) as well as in India, Philippines, Sri Lanka, and Mongolia. In other developing countries, *EI* has only increased moderately. By contrast, the *EI* of Vietnam has increased steadily and surpassed its regional counterparts because the electricity consumption has increased much faster than has GDP through the years. This finding represents empirical evidence for the highly-inefficient used of electricity in Vietnam.

Factor analysis was employed to examine the interrelationships between the economic and electricity indicators in 22 APEs to identify, among others, which of these indicators are the impetus for electricity productivity (*EP*), the inverse of *EI*, across the region. The factor scores shows that Vietnam ranks lowest in terms of *EP*. The factor loading structure suggests that the very low *EP* observed for Vietnam is a consequence of economic growth policies that rely heavily on the electricity-intensive industry sector while lacking market-based mechanisms and effective institutions to support national competitiveness.

Therefore, to improve the productivity of electricity usage, the economic structure should be shifted gradually toward less electricity-intensive activities such as service and information technology. There is also urgent need for institutional and policy reforms to implement a competitive electricity market and phase out state regulation and subsidies for electricity prices. Institutional reform of the state sector is critical to reduce the inefficiency of electricity usage through poorly managed SOEs and inefficient public investment projects.

In reality, a series of comprehensive government reforms in these directions are already in progress and have brought visible results. The electricity prices have been adjusted many times since 2010, high-tech less electricity-intensive manufacturing of smartphones and electronic devices has increasing shares in export values, and the role of the state sector in the economy has shrunk gradually with the expansion of the private sector. Alongside this positive trend is the recent worldwide trend toward using green and renewable energy that has an obvious impact on the energy development policy of APEs, including Vietnam. A new picture of electricity usage in Vietnam may be expected in the years to come that may merit an updated comparative analysis of *EI* in the Asia-Pacific region.

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Appendix

Economic and electricity indicators of 22 APEs used as input variables in factor analysis.

	ACCES	EFFIC	INSTI	LABPR	PCECO	PCGDP	SERVI	TARIF	TDSEF
Australia	100	3.30	5.27	11.32	9.26	10.51	78	22	94.6
Bangladesh	43.6	0.64	3.20	8.76	5.56	6.48	53	6.5	88.8
Brunei	71	0.36	4.86	12.03	9.10	10.13	74	11.5	93.2
Cambodia	50	0.41	3.84	8.32	5.15	6.46	41	12.2	80.0
China	98.9	0.88	4.22	9.62	8.08	8.05	43	8.5	94.0
Hong Kong	100	3.27	5.53	11.49	8.69	10.35	93	18	86.6
Indonesia	90.9	0.61	3.86	9.86	6.53	7.40	47	9.7	90.6
India	68.7	0.93	3.91	9.31	6.54	6.96	55	8	80.3
Japan	100	3.30	5.13	11.15	8.98	10.50	72	22	95.4
Korea	98.9	0.81	3.98	10.99	9.20	10.03	58	10.5	96.5
Laos	68.0	0.73	3.30	8.88	5.94	6.53	37	6.5	80.0
Malaysia	97.9	1.22	4.94	10.77	8.35	8.79	45	9.4	92.9
Mongolia	84.4	1.20	3.34	9.81	7.36	7.29	46	7	87.4
Nepal	74.5	0.42	3.26	8.41	4.72	5.96	48	9.2	67.6
New Zealand	100	3.17	6.06	11.09	9.16	10.24	66	19.1	93.1
Pakistan	85.5	1.28	3.34	9.57	6.12	6.64	53	8	81.8
Philippines	77.3	1.19	3.57	9.55	6.48	7.28	55	9.6	88.2

Singapore	100	2.52	6.07	11.67	9.06	10.47	72	19.8	97.1
Sri Lanka	82.9	1.24	4.24	9.95	6.18	7.47	58	15.5	87.0
Taiwan	100	3.00	5.00	11.38	9.38	9.83	50	12	95.7
Thailand	91.1	1.06	3.82	10.02	7.76	8.16	43	7.9	93.8
Vietnam	92.6	0.48	3.61	8.92	7.03	6.85	38	6.04	91.0

PCGDP in 2010 US$, log transformed; PCECO in kWh, log transformed; LABPRO in current US$, TARIF in current US cent; SERVI and TDSEFF in %. Data are averages for the 2009–2013 period.

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