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OWNERSHIP AND ENERGY CONSUMPTION IN VIETNAM: A PANEL DATA ANALYSIS OF ECONOMIC SECTORS

Pham Thi Ha [†]

This study empirically examines the relationship between total energy including electricity, coal, coal briquette, engine/motor oil, kerosene, fuel oil, diesel, LPG, and natural gas for three economic sectors including state economic sector, non-state economic sector and foreign economic sector in Vietnam from 2000 to 2015. The results indicate that Vietnamese economy is an energy-dependent economy; the non-state economic sector depends on energy consumption significantly, whereas the foreign economic sector is opposite. The result of state economic sector is insignificant statistically, therefore it is inconclusive. Besides, the results suggest that coal and coal briquette are important fuel for economic growth, especially for the foreign economic sector.

Keywords: output, energy consumption, state economic sector, non-state economic sector, foreign economic sector.

1. Introduction

This paper asks whether plants controlled by foreign multinational corporations (MNCs) used energy (defined as electricity, coal, coal briquette, engine/motor oil, kerosene, fuel oil, diesel, LPG, and natural gas) more efficiently than local plants covered in Vietnam during the period between 2000 and 2015. Answering this question is important because energy consumption is a large source of portion of pollution (mainly air pollution) generated by manufacturing plants. Greater energy conservation generally implies increased energy efficiency and is an important way to limit or reduce related pollution. Correspondingly, if foreign MNCs produce efficiently than local plants or firms in host economies as often asserted, they may contribute directly to lower pollution intensity in the host and may also help create spillovers that lead local plants and firms to adopt more energy-saving technologies.

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Eskeland and Harrison (2003) is one of the few, recent studies using micro-data to investigate this question in developing economies. One of their main findings (p. 21) was "foreign plants are significantly more energy-efficient and use cleaner types of energy" than their local peers in Côte d'Ivoire, Mexico, and Venezuela. In a related study of provincial data, He (2006) provides evidence that FDI enterprises produce "with higher [SO_2] pollution efficiency", but that stronger environmental regulation has simultaneously, though moderately, deterred FDI among Chinese provinces. Earnhart and Rizal (2006) focus on the effects of financial performance and privatization on environmental performance, but their results also indicate foreign ownership was usually an insignificant determinant of pollution in Czech firms.

This paper will contribute to energy economics literature and Vietnamese economy in at least a few ways. First, this study analyzes the relationship between economic growth and energy consumption in Vietnam using panel data for total of three economic sectors in Vietnam including state economic sector, private economic sector and foreign economic sector for the period from 2000 to 2015. Second, energy consumption includes nine groups of energy that is, electricity, coal, coal briquette, engine/motor oil, kerosene, fuel oil, diesel, LPG, and natural gas. Thus, it is strongly believed that the findings of this study would be a reliable and suitable basis for policymaking. The rest of this paper is organized as follows. Section 2 reviews literature, Section 3 discusses the theoretical framework, data, and methodology in this study. The results and conclusions are presented in Section 4 and 5, respectively.

2. Literature review

MNCs will tend to be relatively efficient producers compared to non-MNCs at least in some respect thanks to have relatively large amounts of knowledge-based and intangible assets. And this relatively high efficiency could involve the MNCs becoming more energy efficient and/or polluting less as part of efforts to facilitate increased demand among consumers and minimize production costs related to energy and pollution abatement. Moreover, because MNCs tend to be relatively R&D- and patent-intensive, and because technologies for clean energy and pollution control usually require relatively sophisticated, technological inputs, it is logical to expect that MNCs are relatively efficient producers and consumers of goods and services that promote energy efficiency and pollution reduction. For example, evidence from Cole et al. (2006) suggests that Japanese firms with FDI tend to have better environmental performance (pollute less and manage emissions better) than firms without FDI. This is consistent with the notion that MNCs are both better able to and more highly motivated to pollute less than other firms. Although limited, most of the existing literature on energy intensities indicates that MNCs tend to be relatively energy efficient, and thus tend to pollute less, than local counterparts. However, even if MNCs are relatively energy efficient or pollute relatively little, they may still contribute to higher absolute pollution levels if they stimulate substantially higher production levels.

A study of Indonesian plants in 2002-2006 by Hartono et al. (2011) indicates that local, private plants tended to have significantly higher energy intensities than state-owned enterprises (SOEs, which is the control group in their study), but that MNC-SOE differentials in energy intensities were not significant statistically. In other words, their evidence suggests that MNCs and SOEs use with similar efficiency and that SOEs are more energy efficient than private plants. Ramstetter et al (2012) examined energy efficiency differentials between foreign multinational corporations (MNCs) and local plants in Thai manufacturing using data on medium-large plants from the industrial census for 2006. Both descriptive statistics and results of econometric estimation indicate that MNCs had a moderate tendency to use energy relatively efficiently, especially in food products, plastics, basic metals, and non-metallic mineral products. However, differences in energy intensities between MNCs and local plants were not common, suggesting that both groups of plants generally used energy with similar efficiency. In other paper, Ramstetter et al (2013) examined whether foreign MNEs used energy more efficiently than their local counterparts in samples of medium–large plants in the manufacturing sectors of Malaysia, Indonesia, and Thailand during 1996-2006. The results reveal that the influences of plant-level factor usage and technical characteristics, foreign multinational enterprises (MNEs) used fuel and total energy more efficiently than local manufacturing plants in about one-third of Malaysia's large energy using industries. MNE-local or MNE-private differentials were insignificant, however, in most industries for electricity in Malaysia; total energy, electricity and three fuels (diesel, natural gas, and coal) in Indonesia; and total energy in Thailand. In short, MNEs and local or private plants generally used purchased energy with similar efficiency, probably because they faced similar host country policies and used similar energy technologies.

In Vietnam, state-owned enterprises are expected to be more responsive to the public or government needs that private firms and the government has emphasized how state-owned enterprises should play leading roles in industry and that private firms should seek to cooperate with state-owned enterprises (Vu 2005, pp. 304-306). Thus, if the government puts a priority on low pollution and/or abatement of emissions, then it is reasonable to expect that SOEs might be more motivated to pollute less and abate more than private firms. However, it is difficult to argue convincingly that the Vietnamese government has put a high priority on pollution reduction or abatement in the last decade, for example, or that the government has emphasized energy efficiency or low pollution when operating its SOEs. Thus, if the SOEs in Vietnam pollute relatively little, it is probably more related to differences in technical characteristics of the firms and the fact that the Vietnamese government chooses to own SOEs that are often relatively sophisticated technologically compared to private firms. As in the comparison of MNCs and non-MNCs, the fact that one group possesses more technology-related assets than the other is the key, differentiating characteristic.

3. Methodology and data

3.1. Methodology

3.1.1. Panel unit roots

We apply Levin et al (1993) (LLC), lm et al (1997) (IPS), Maddala and Wu (1999) (MW, ADF) and Maddala and Wu (1999) (MW, PP) panel unit root tests to check the stationarity properties of the variables. These tests apply to a balanced panel but the LLC can be considered a pooled panel unit root test, IPS represents a heterogeneous panel test and MW panel unit root test is a non-parametric test.

3.1.2. Panel cointegration

We then proceed to examine whether there exists any long-run equilibrium relationship between the variables under investigation. We resort to Pedroni (1999, 2001, and 2004) and Kao (1999) panel cointegration tests.

Pedroni (1999) uses the following cointegration equation:

$$GDP_{i,t} = \alpha_i + \beta_{1i}EC_{1i,t} + \cdots + \beta_{mi}EC_{mi,t} + \mu_{it} \quad (1)$$

Where GDP is real per capita GDP and EC is per capita energy consumption including electricity, coal, coal briquette, engine/motor oil, kerosene, fuel oil, diesel, LPG, and natural gas; subscripts i and t represent economic sector and year, respectively. GDP and EC are assumed to be integrated of order one. The specific intercept term α_i and slope coefficients $\beta_{1i}, \beta_{2i},...,\beta_{mi}$ vary across individual members of the panel. Pedroni (1999, 2004) proposed seven different statistics to test for cointegration relationship in a heterogeneous panel. These tests are corrected for bias introduced by potentially endogenous regressors. In the presence of cross-sectional dependence, Pedroni suggests the inclusion of common time dummies to eliminate this effect. Pedroni considers seven different statistics, four of which are based on pooling the residuals of the regression along the within-dimension (panel test) of the panel. The other three are based on pooling the residuals of the regression along the between-dimension (group test) of the panel. The within-dimension tests take into account common time factors and allow for heterogeneity across individuals. The between-dimension tests are the group-mean cointegration tests, which allow for the heterogeneity of parameters across individuals.

Kao (1999) proposed Dickey Fuller (DF) and ADF-type test for ε_{it}, where the null is specified as no cointegration.

3.1.3. Panel Fully Modified OLS (FMOLS) Estimates

If all the variables are cointegrated, the next step is to estimate the associated long-run cointegration parameters. In the presence of cointegration, the OLS estimator is known to yield biased and inconsistent results. For this reason, several estimators have been proposed. For example, Kao and Chiang (2000) argue that their parametric panel dynamic OLS (DOLS) estimator (that pools the data along the within the dimension of the panel) is promising in small samples and performs well in general in cointegrated panels. However, the panel DOLS of Kao and Chiang (2000) does not consider the importance of cross-sectional heterogeneity in the alternative hypothesis. To allow for cross-sectional heterogeneity in the alternative hypothesis, endogeneity, and serial correlation problems to obtain consistent and asymptotically unbiased estimates of the cointegrating vectors, Pedroni (2000, 2001) proposed the group mean fully modified OLS (FMOLS) estimator for cointegrated panels

3.1.4. Panel VECM causality

We estimate a panel based vector error correction model (VECM) with a dynamic error correction term based on the analysis in Holtz-Eakin et al (1988, 1989). The following VECM models are used to test the causality relation between variables:

$$\Delta GDP_{it}=\pi_{1j}+\sum_{p=1}^{m}\pi_{11ip}\Delta GDP_{it-p}+\sum_{p=1}^{m}\pi_{12ip}\Delta EC_{it-p}+\mu_{1i}ECT_{it-1}+v_{1it} \quad (2)$$

$$\Delta EC_{it}=\pi_{2j}+\sum_{p=1}^{m}\pi_{21ip}\Delta EC_{it-p}+\sum_{p=1}^{m}\pi_{22ip}\Delta GDP_{it-p}+\mu_{2i}ECT_{it-1}+v_{2it} \quad (3)$$

Where Δ is the lag operator and p denotes the lag length. The specification in Equation (2) allows for testing the causality direction. For example, in the short − run, the EC does not Granger cause GDP where $H_0: \pi_{12ip}=0$ for all i and p, while $\mu_{1i}=0$ in equation (2). The rejection implies that EC→GDP, supporting the growth hypothesis. Similar analogous restrictions and testing procedures can be applied in testing the hypothesis that GDP does not Granger cause movement in EC, where the null hypothesis $H_0: \pi_{22ip}=0$ for all i and p, while $\mu_{2i}=0$ in equation (3).

Similarly, we estimate a panel based vector error correction model for GDP, and each kind of energy.

3.2. Data

Annual data from 2000 to 2015 for three economic sectors including state economic sector, non-state economic sector and foreign economic sector in Vietnam were utilized for the study. The energy consumption including electricity, coal, coal briquette, engine/motor oil, kerosene, fuel oil, diesel, LPG, and natural gas were obtained from the statistical yearbooks of General Statistics Office of Vietnam. In this study, per capita total energy consumption is expressed in terms of millions Vietnam dong, and real per capita GDP is expressed in constant 2000 billion Vietnam dong. All variables are transformed into natural logarithms to reduce hetetoskedasticty.

4. Empirical results

4.1. Panel unit root results

Appendix 1 presents the estimated results of unit root tests at level and first difference. These results are calculated by applying panel unit root tests: LLC, LM, ADF, and PP on each selected variable without trend, with trend and without trend and intercept. Our empirical findings illustrate that all variables (without trend and intercept) are non-stationary in their level form. However, all the series are stationary at first difference. Thus, we reject the null hypothesis of non-stationary at 1% level of significance and conclude that all series are integrated of order one I (1) in the panel of three economic sectors in Vietnam.

4.2. Panel cointegration results

From the panel cointegration result in Table 1, for Kao (1999) panel cointegration test, we reject the null hypothesis of no cointegration using the ADF-type statistics; this suggests that the variables in the model for all economic sectors are cointegrated and move together in the long-run. Thus we find that GDP and 9 groups of energy are cointegrated in the panel setting for the same period[1].

At the same time, the causality relationship between per capita GDP and total energy (including 9 groups of energy) is also estimated. From Table 2, we find pretty strong evidence to reject the null hypothesis of no cointegration for six statistics out of seven statistics provided by Pedroni (1999, 2001, 2004). The result of Kao test illustrates that per capita GDP and total energy are cointegrated in the panel for the period from 2000 to 2015.

Table 1. Kao conintegration test for GDP and 9 groups of energy

Kao Residual Cointegration test	
Test	ADF
Statistic	-3.0757
P-value	0.0010

1 We cannot apply Pedroni residual cointegration test for the model of GDP and 9 groups of energy due to the number of variables are greater than 7 ones, and it cannot be applied this test.

Table 2. Panel Cointegration Tests Results for GDP and total EC

A: Pedroni Residual Cointegration test							
Panel cointegration statistics (within-dimension)					Group mean panel cointegration satistics (between-dimension)		
Test	Panel v-Statistic	Panel rho-Statistic	Panel PP-Statistic	Panel ADF-Statistic	Group rho-Statistic	Group PP-Statistic	Group ADF-Statistic
Statistic	1.5365	−1.6470	−3.5193	−4.1855	−1.0953	−5.9574	−5.9513
P-value	0.0622	0.0498	0.0002	0.0000	0.1367	0.0000	0.0000
B: Kao Residual Cointegration test							
Test				ADF			
Statistic				−2.3829			
P-value				0.0086			

Note: Probability values are in parenthesis

4.3. Panel FMOLS Estimates

Having established cointegration in the long-run, we estimate the long-run parameters of the model by using the FMOLS technique. The FMOLS corrects the standard OLS for the bias induced by endogeneity and serial correlation of the regressors (Lee, 2005). The elasticity of energy consumption is important for understanding the past and assessing future economic dynamics. It represents the weights with which the marginal relative changes of the energy consumption contributes to the relative change of output (Lee et al., 2008).

Table 3. FMOLS estimates

No	Engergy	Panel estimates	State economic sector	Non-sate economic sector	Foreign economic sector
1	Electricity	−0.5357**	0.0899	0.0180	0.2183
2	Coal	−0.0415	−0.0314	−0.2570*	0.6705***
3	Coalbr	0.07352**	0.1339	0.1700***	0.0822**
4	Engineoil	−0.1430***	−0.2033***	−0.2365***	0.3108**
5	Kerosene	−0.1429**	−0.2506**	−0.1217*	−0.1478
6	Fueloil	−0.0531	0.0998*	−0.2046**	0.193
7	Diesel	−0.2645	0.0371	−0.7424**	2.0730***
8	Natural Gas	0.0544	0.1284	0.3660***	−0.1998**
9	LPG	0.0956	0.0621	0.0516	0.1876
10	EC	1.3693**	0.3026	1.1448**	−2.6978**

Note: The values in parentheses are the t-statistics. Asterisks ***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

Table 3 reports the results of the long-run estimates for three economic sectors in Vietnam and the panel estimates based on Pedroni's group mean FMOLS estimator. The panel results of the regression equation with real per capita GDP as the dependent variable illustrate that the coefficient of total energy is positive and statistically significant at 5 per cent significance level. A one per cent increase in energy consumption leads to around 1.3696 per cent increase in real per capita GDP. The coefficient of total energy consumption is greater than 1; it suggests that Vietnamese economy is an energy dependent one. This is consistent with Tang et al (2016). When we consider different kinds of energy, only four out of nine coefficients are significant. The coefficient of coal briquette is positive and significant at 5 per cent level. It illustrates that a one per cent increase in coal briquette will result in approximately 0.073 per cent in GDP growth. By contrast, the coefficients of electricity, engine oil, and kerosene are significant at 1 and 5 per cent level but they are negative. These results reveal that the use of these fuels is decreasing in Vietnamese economy, and they are switching to new kinds of energy.

In state economic sector, the coefficient of total energy is positive, but it is insignificant. Specifically, three out of nine coefficients are significant. The coefficient of fuel oil is positive and significant at 5 per cent level, it suggests that fuel oil is very important fuel in the state economic sector, and it will contribute to approximately 10 per cent the total output of the state economic sector. The coefficients of engine oil and kerosene are the same to panel estimates; hence it has the same pattern to the panel results.

When it comes to non-state economic sector, the coefficient of total energy is significant and it is greater than 1, it suggests that the non-state economic sector depends greatly on energy consumption, especially coal briquette and natural gas when their coefficients are 0. 17, 0. 366 respectively and significant at 1 per cent level. In addition, the coefficients of coal, engine oil, fuel oil and diesel are significant, but they are negative. Also, this evidence suggests that the non-state economic sector is less energy efficient. This is consistent with Hartono et al. (2011).

Interestingly, in the last economic sector, the coefficient of total energy is negative significantly (−2.6978). It shows that the foreign economic sector is an independent-energy sector, otherwise whether foreign MNEs used energy more efficiently than their local counterparts in samples. This is supported by Ramstetter et al (2013). In detail, the coefficients of coal, coal briquette, engine oil and diesel are significant statistically, and they contribute approximately 0.67, 0.08, 0.32, and 2.07 per cent to the growth of output. In contrast, the coefficient of natural gas is negative statistically. These results suggest that in the foreign economic sectors, enterprises tend to use energy more efficiently than local ones; however they use coal, and coal briquette significantly, which result in increasing the level of pollution in Vietnam.

4.4. Panel Granger Causality Test Results

Once the long-run estimates have been determined, we turn to the causality linkages. Table 4 reports panel Granger causality between economic growth and total energy consumption. In GDP equation, ECT is significant at 10 per cent level but it is positive, indicating that there is no long run causality from energy consumption to GDP. Since the estimated coefficients of the explanatory variables are statistically insignificant; hence there is no short-run causality linkage from energy consumption to outputs.

In the EC equation, ECT is negative and significant statistically at 1 per cent level; therefore there is long-run causality from GDP to EC; but there is no short-run causality from GDP to EC.

Table 5 reports Granger causality between GDP and each kind of energy consumption. For the GDP equation, there is short-run causality from natural gas to GDP, whereas there is not any causality from GDP to each kind of energy consumption. For the coefficients of ECT, only in the equation of coal, there is long-run causality from GDP and electricity, coal briquette, engine/motor oil, kerosene, fuel oil, diesel, LPG, and natural gas. This evidence suggests that coal is one of crucial fuels for the development of Vietnamese economy.

All in all, from the panel results of FMOLS test and panel Granger causality test, energy consumption brings a positive impact on the outputs in the long-run, and in the short-run, there is no Granger causality among variables. The non-state economic sector is energy dependent, while the foreign economic sector is energy independent increase the outputs. However, coal and coal briquette contribute significantly on the outputs of the foreign-economic sector. The outcome of state-economic sector is inconclusive, and this is supported by Ramstetter (2011).

Table 4. Panel Granger Causality test results

Dependent variables	Source of causation (independent variables): Δlngdp Short run	Δlnec	ECT Long run
Δlngdp	–	0.2560	0.0078*
	–	1.6168	[1.7624]
Δlnec	−0.3152	–	−0.0791***
	[−1.6582]	–	[−4.2213]

Note: Wald F-statistics reported with respect to short-run changes in the independent variables. ECT represents the coefficient of the error correction term. Values in [ ] are t-ratios. ***, * Significance at 1%, 10 % level, respectively.

Table 5. Panel Granger Causality test results for each kind of energy

Dependent variables	Source of causation (independent variables)										
	Δlngdp Short run	Δlnelectricity	Δlncoal	Δlncoalbr	Δlnengineoil	Δlnkerosene	Δlnfueloil	Δlndiesel	Δlnnaturalgas	Δlnlpg	ECT Long run
Δlngdp	-	0.1106	0.0265	−0.0954	0.0025	−0.0892	−0.0670	−0.0435	0.2040**	0.0068	0.0016
	-	[0.8770]	[0.2161]	[0.1717]	[0.9783]	[0.5300]	[0.4721]	[0.8038]	[0.0410]	[0.9458]	[0.0778]
Δlnelectricity	−0.1238	-	0.1576	0.0708	−0.0880	0.0642	0.1071	−0.4210	0.1080	0.0410	0.1365*
	[−0.3672]	-	[−0.7361]	[0.5963]	[−0.5485]	[0.2623]	[0.6673]	[−1.3897]	[0.6488]	[0.2341]	[1.8268]
Δlncoal	−0.1543	0.0589	-	0.1226	0.4085***	−0.9081**	−0.2956	1.0186**	−0.0808	0.1910	−0.5160**
	[−0.3260]	[0.1908]	-	[0.7398]	[1.8136]	[−2.6424]	[−1.3118]	[2.3950]	[−0.3456]	[0.7769]	[−1.2962]
Δlncoalbr	−0.5244	0.6956**	−0.4313	-	−0.3564	0.0881	0.3416	0.2169	0.3337	−0.2903	−0.0921
	[−1.0107]	[2.0568]	[−1.3095]	-	[−1.4440]	[0.2340]	[1.3836]	[0.4654]	[1.3020]	[−1.0777]	[−1.5275]
Δlnengineoil	0.2770	−0.2674	−0.4613	0.0283	-	−0.0043	0.8161***	−0.3985	0.2804	−0.2456	−0.3174***
	[0.6273]	[−0.9290]	[−1.6459]	[0.1822]	-	[−0.0137]	[3.8832]	[−1.0047]	[1.2856]	[−1.0711]	[−4.1392]
Δlnkerosene	0.2587	−0.0378	0.1983	−0.4179**	0.1324	-	0.5672**	−0.6813	0.4137	−0.1646	0.0237
	[0.5565]	[−0.1247]	[0.6722]	[−2.5528]	[0.5987]	-	[2.5637]	[−1.6318]	[1.8019]	[−0.6821]	[0.5875]
Δlnfueloil	−0.3383	−0.4789**	−0.418***	−0.0201	−0.0787	0.0944	-	0.1312	0.1185	−0.2035	−0.4672***
	[−1.0021]	[−2.1766]	[−1.9508]	[−0.1697]	[−0.4906]	[0.3853]	-	[0.4326]	[0.7111]	[−1.1609]	[−3.8567]
Δlndiesel	−0.3207	−0.2248	0.3670	−0.2169***	−0.0089	0.5865**	0.8518***	-	0.5176***	0.0188	−0.0197***
	[−0.8959]	[−0.9636]	[1.6156]	[−1.7213]	[−0.0523]	[2.2576]	[5.0003]	-	[2.9278]	[0.1011]	[−1.9772]
Δlnnaturalgas	−0.6682	0.1545	0.5478*	0.0504	0.1627	0.6484*	0.6592***	−0.6194	-	−0.2398	−0.0253
	[−1.5010]	[0.5326]	[1.9386]	[0.3220]	[0.7684]	[2.0070]	[3.1114]	[−1.5492]	-	[−1.0374]	[−0.9051]
Δlnlpg	−0.7121	−0.0690	0.5255*	−0.0325	0.2684	0.2175	0.4042*	−0.1779	0.5325**	-	−0.0023
	[−1.5483]	[−0.2303]	[1.8004]	[−0.2008]	[1.2270]	[0.6515]	[1.8467]	[−0.4370]	[2.3441]	-	[−0.2698]

Note: Wald F-statistics reported with respect to short-run changes in the independent variables. ECT represents the coefficient of the error correction term. Values in [ ] are t-ratios. ***, **, * Significance at 1%, 5%, 10% level, respectively.

5. Conclusion

Using panel estimation for three economic sectors in Vietnam, this study empirically examines the relationship between total energy including electricity, coal, coal briquette, engine/motor oil, kerosene, fuel oil, diesel, LPG, and natural gas. We find that the variables were in a stationary fashion in their first differences or were in an I(1) process. The panel cointegration results reveal a long-run equilibrium relationship among the variables, and it indicates that Vietnamese economy is an energy-dependent economy. When we consider each economic sector separately, the non-state economic sector depends on energy consumption significantly, whereas the foreign economic sector is opposing. The result of state economic sector is insignificant statistically, therefore it is inconclusive. Besides, the results suggest that coal and coal briquette are important fuel for economic growth, especially for the foreign economic sector.

From the Granger causality test, there is no short-run causality relationship between the output and energy consumption, except for the model of coal.

The research results reveal that high level of energy consumption results in a high level of outputs, but not vice versa. Thus, for the policy perspective, the Vietnamese government can pursue energy policies that aim at curtailing energy use for environmental-friendly development purposes. At the same time, the market competitiveness of the traditional energy market and renewable energies could be gradually established, and improve alternative sources of energy or renewable energy such as hydropower, forest and biomass power, wind and solar power, and geothermal power. These suggestions in line with the National Plan for Environment and Sustainable Development which aims to develop the eco-friendly energy sector in Vietnam.

This study just focuses on the bivariate causality tests for energy consumption and economic growth for three economic sectors in Vietnam during the period from 2000 to 2015. Further studies can be done by using longer time series and using data by industry for the state-economic sector, non-state economic sector, and foreign economic sector.

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Appendix 1. Panel unit root test results

Variables	At level						At first difference					
	without trend	P-value	with trend	P-value	None	P-value	without trend	P-value	with trend	P-value	None	P-value
LLC test												
lngdp	2.1358	0.0163	0.72109	0.2354	7.2123	1.0000	9.4882	0.0000	4.5108	0.0000	3.5783	0.0002
lnelectricity	0.085	0.4661	3.3742	0.0004	12.6598	1.0000	6.3991	0.0000	6.0023	0.0000	0.6563	0.2558
lncoal	3.103	0.001	0.0516	0.4794	3.4704	0.9997	2.165	0.0152	4.4305	0.0000	2.7122	0.0033
lncoalbr	1.3979	0.0811	0.3862	0.3497	5.1915	1.0000	5.8462	0.0000	5.0076	0.0000	4.0267	0.0000
lnengineoil	2.2452	0.0124	5.8072	1.0000	1.0785	0.8596	1.0035	0.8422	1.937	0.0264	2.1527	0.0157
lnkeresone	0.1356	0.4461	0.1278	0.5509	6.0157	1.0000	4.1248	0.0000	3.7065	0.0001	2.8736	0.0020
lnfueloil	3.563	0.0002	2.2753	0.9886	4.4114	1.0000	2.9314	0.0017	0.7800	0.7823	3.6083	0.0002
lndiesel	2.2343	0.0127	5.3047	1.0000	4.3548	1.0000	0.5627	0.2868	2.5513	0.0054	3.1362	0.0009
lnlpg	1.5135	0.0651	0.9796	0.8364	5.1153	1.0000	4.3291	0.0000	3.7961	0.0001	3.7456	0.0001
lnnaturalgas	2.2613	0.0119	2.0664	0.9806	5.5949	1.0000	4.3959	0.0000	3.3149	0.0005	2.2295	0.0129
Im, Pesaran and Shin W-stat												
lngdp	0.0727	0.471	1.4502	0.0735			8.2592	0.0000	4.5442	0.0000		
lnelectricity	2.184	0.9855	1.2798	0.1003			5.1689	0.0000	3.8082	0.0001		
lncoal	1.3194	0.0935	1.545	0.9388			1.4511	0.0734	2.8951	0.0019		
lncoalbr	1.1972	0.8844	0.9577	0.8309			4.0263	0.0000	2.7802	0.0027		
lnengineoil	0.3259	0.3722	6.1834	1.0000			0.7736	0.7804	0.3779	0.6473		
lnkeresone	1.9896	0.9767	1.0547	0.1458			3.7516	0.0001	1.9461	0.0258		
lnfueloil	1.3664	0.0859	1.5976	0.9449			3.0177	0.0013	2.4984	0.0062		
lndiesel	0.1104	0.456	3.5189	0.998			1.2128	0.1126	0.6579	0.2553		
lnlpg	0.6265	0.7345	1.7674	0.9614			3.1384	0.0008	1.487	0.0685		
lnnaturalgas	0.1107	0.5441	2.2166	0.9867			3.7873	0.0001	1.778	0.0377		
ADF - Fisher Chi-square												
lngdp	4.3692	0.6268	12.9046	0.0446	0.0052	1.0000	47.4309	0.0000	27.1347	0.0001	22.9893	0.0008
lnelectricity	0.9816	0.9863	11.0976	0.0854	0.0002	1.0000	32.5513	0.0000	23.3111	0.0007	8.5998	0.1974
lncoal	10.2865	0.1131	1.4599	0.9621	0.1018	1.0000	11.8743	0.0648	19.0169	0.0041	13.7836	0.0321

lncoalbr	2.5081	0.8676	2.8184	0.8313	0.0165	1.0000	25.2174	0.0003	17.7599	0.0069	23.0083	0.0008
lnengineoil	5.3164	0.5039	0.0043	1.0000	2.0063	0.9191	2.6675	0.8493	3.4137	0.7554	10.5305	0.1040
lnkeresone	0.7554	0.9932	8.6032	0.1971	0.0057	1.0000	23.5709	0.0006	13.105	0.0414	14.6857	0.0228
lnfueloil	9.9216	0.0128	1.1889	0.9774	0.035	1.0000	19.2524	0.0038	16.5799	0.0110	19.352	0.0036
lndiesel	4.5421	0.6037	0.118	1.0000	0.0367	1.0000	9.2643	0.1593	7.0679	0.3146	16.2613	0.0124
lnlpg	2.7216	0.8429	1.0424	0.9840	0.0145	1.0000	19.8943	0.0029	11.3133	0.0792	20.8336	0.0020
lnnaturalgas	3.9180	0.6878	2.00866	0.9189	0.0065	1.0000	23.7944	0.0006	15.7663	0.0151	11.2854	0.0799
PP - Fisher Chi-square												
lngdp	3.69232	0.7182	1.00485	0.9854	0.01454	1.0000	19.4883	0.0034	24.9098	0.0004	20.7443	0.0020
lnelectricity	160000	1.0000	0.07941	1.0000	0.00042	1.0000	10.4205	0.1080	24.7407	0.0004	10.1531	0.1184
lncoal												
lncoalbr	4.42566	0.6193	2.90418	0.8208	0.00707	1.0000	31.4090	0.0000	33.2215	0.0000	22.6626	0.0009
lnengineoil	5.37939	0.4962	0.00499	1.0000	0.24209	0.9997	2.05410	0.9147	1.27005	0.9733	9.96774	0.1260
lnkeresone	0.73154	0.9938	7.28234	0.2955	0.00266	1.0000	22.8627	0.0008	12.0874	0.0600	18.1327	0.0059
lnfueloil	13.3197	0.0382	0.27878	0.9996	0.03424	1.0000	18.9640	0.0042	22.6049	0.0009	23.9134	0.0005
lndiesel	4.58139	0.5985	0.12152	1.0000	0.04304	1.0000	9.26422	0.1593	5.61228	0.4680	15.9823	0.0138
lnlpg	3.69232	0.7182	1.00485	0.9854	0.01454	1.0000	19.4883	0.0034	24.9098	0.0004	20.7443	0.0020
lnnaturalgas	4.82780	0.5661	1.85288	0.9327	0.00525	1.0000	23.8526	0.0006	26.8626	0.0002	22.3006	0.0011