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An analysis of CO2 emissions, energy consumption, economic growth and foreign direct investment in Thailand

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Abstract-The aim of this study is to understand the relationship between CO_2 (carbon dioxide) emissions, energy consumption, economic growth and FDI (foreign direct investment) in Thailand during the period from 1988 to 2014. This study use cointegration and Granger causality to examine the relationship between the variables. The results confirm the existence of long-run equilibrium among all four variables. Meanwhile, energy consumption and FDI positively influence CO2 emissions. Moreover, square of economic growth has negative impact on CO2 emissions in Thailand. The results also reveal that there are two way causalities between CO2 emissions and energy consumption in Thailand. Given the result that square of economic growth has negative impact on CO_2, these findings support the EKC(Environmental Kuznets Curve) hypothesis which assumes an inverted U-shaped relationship between CO2 emissions and economic growth in Thailand. In addition, energy consumption is found to Granger cause CO2 emissions in the short-run and long-run. The key determinants of CO_2 emissions in Thailand are Energy consumption, FDI and economic growth. Therefore, adoption of clean technologies and green policy by Investors and policy makers are important in reduce CO_2 emissions in Thailand, also important in accelerate economic development and sustaining economic development at the same time.

Keywords-Carbon dioxide emissions, Energy consumption, economic growth, FDI(Foreign Direct Investment), Thailand.

1. Introduction

The debate about the relationship between energy consumption and economic development stems from the increasing effects of energy on economic development. Nevertheless, Economic development today is global. Many companies are taking part in the global distribution of investment, and many countries encourage the use of foreign investment to promote their economic growth. However, the environmental problems hidden behind this situation should not be overlooked. In recent years, air pollution and global climate change issues caused by greenhouse gases have become the focus of international attention Hsiao-Tien and Chung-Ming [1]. With growing concerns about global warming or climate change, there is a pressure for nations to consume a balanced level of energy that control the emissions to the environment; but at the same time ensuring the country's sustainable economic growth. Due to economic development and population increase, electricity demand growth in developing countries has contributed to increasing CO2 emissions in the power sector . In the recent years,

it has been acknowledged that adverse effects of climate change needs to be studied over a long period [2]. CO2 (Carbon dioxide) emissions appear to be the major contributor of global warming [3]. As developing countries continue to grow, their CO2 emissions have become an important issue in international agreements pertaining to the ingress of FDI (foreign direct investment) and the quality of environment [4]. Thailand's load forecast is expected to increase by 4.13% per year or 9,793 GWh per year during 2012-2030 [5]. The main fuel for power generation in Thailand is natural gas which accounted for 72.8% of total power generation in 2010. Coal and lignite were also used by 19.8%. A small proportion of heavy oil was used by 0.7% due to expensive energy resource [6]. The dependence of natural gas in power generation has been concerned with the security of electricity supply in terms of fuel diversification. Signed in 1997, the Kyoto Protocol to the United Nations Framework Convention on Climate change (UNFCCC) requires reduction of greenhouse gas (GHG) emissions by industrialized countries. Developing countries such as Thailand are not legally required by the protocol to reduce the GHG emission [7]. However, environmental protection is a serious challenge in power sector development to be a part of low carbon society. The power generation expansion planning (PGEP) needs to consider more efficient generating technologies for satisfying the electricity demand growth. Thus, Thailand launched two important plans which are the 20-year Thailand Power Development Plan (PDP) of 2010-2030 and the 10-year Alternative Energy Development Plan (AEDP) of 2012-2021. PDP 2010 substantially focuses on energy security and sufficiency of power generation. Meanwhile, AEDP promotes the aspects of environmental concern and renewable energy utilization. Testing the relationship between economic growth and environmental pollution under the Environmental Kuznets Curve (EKC) hypothesis forms the first group of related literatures. The EKC hypothesis claims an inverted U-shaped relationship between environmental pollution and income per capita. Ang[8] argues an inverted U-shaped relationship between CO2 emissions and output for France thus suggesting the evidence of EKC. He found a long-run relationship between output, CO2 emissions and energy consumption with a causal relationship from output to energy consumption and CO2

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emissions in the long run and from energy consumption to economic growth in the short-run. However related empirical studies are inconclusive. Although Behnaz and Jamalludin [9]. In light of these, we carry out an investigation on the relationship between CO2 , FDI, energy consumption and economic growth in Thailand. This study does not merely provide some insights into the impact of FDI, energy consumption and economic growth on CO2 emissions, but the framework of this study also allows us to ascertain the validity of FDI led growth, energy led growth and the pollution haven hypotheses in Thailand. Therefore, the findings of this study are expected to provide useful information to policy makers in drawing up effective environmental and economic growth policies. Section 2 and 3 will presents overview of the economy of Thailand and the empirical studies, respectively. The methodology and data used for this study will be introduced in Section 4. The empirical results will be reports in Section 5 and Section 6 concludes the paper and suggests policy implications.

2. Overview of the Thailand Economy

Thailand is a newly industrialized country. Its economy is heavily export-dependent, with exports accounting for more than two-thirds of its gross domestic product (GDP). In 2012, according to the Office of the National Economic and Social Development Board, Thailand had a GDP of THB11.375 trillion (US$366 billion) [10]. The Thai economy grew by 6.5%,[10] with a headline inflation rate of 3.02%[11] and an account surplus of 0.7% of the country's GDP[12]. In 2013, the Thai economy is expected to grow in the range of 3.8–4.3%[13]. During the first half of 2013 (Q1-Q2/2013), the Thai economy grew by 4.1% (YoY)[13]. Given a contraction in two consecutive quarters, the Thai economy is now in recession. The industrial and service sectors are the main sectors in the Thai gross domestic product, with the former accounting for 39.2% of GDP. Thailand's agricultural sector produces 8.4% of GDP – lower than the trade and logistics and communication sectors, which account for 13.4% and 9.8% of GDP respectively. The construction and mining sector adds 4.3% to the country's gross domestic product. Other service sectors (including the financial, education and hotel and restaurant sectors) account for 24.9% of the country's GDP[14]. Telecommunications and trade in services are emerging as centers of industrial expansion and economic competitiveness[15,16]. The government of Thailand has focused on the social and economic development of the country for the past 35 years. However, since Thailand introduced the Seventh Economic and Social Development Plan (1992-1996)[17], protecting the environment has become one of the top priorities of the Thai government. The Seventh Economic and Social Development Plan seeks to achieve sustainable growth and stability, especially in the petrochemical, engineering, electronics, and basic industries[18]. Industrial growth has created high levels of air pollution and energy consumption in Thailand(Fig.1). Vehicles and factories contribute to air pollution, particularly in Bangkok[19].

Industrial waste is the waste produced by industrial activity which includes any material that is rendered useless during a

Fig. 1. Proportion of Thailand's 2012 energy consumption.
Source: Vatanavong and Sajjakaj (Article in Press)

mining operations. It has existed since the start of the Industrial Revolution[20]. Some examples of industrial waste are chemical solvents, paints, sandpaper, paper products, industrial by-products, metals, and radioactive wastes.

3. Empirical Studies

CGE model was built to analyse the effects of investment growth in the energy sectors of western areas of China on the local economy and emission of carbon dioxide (CO2). The results show that when the investment growth is at 0–60%, the GDP growth is at 0–8.92%, households disposable income growth is at 0–8.94%, and emission of carbon dioxide growth is at 0–11.10%. Moreover, The oil and gas sector is the most effective sector with a growth rate[21]. Ferda[22] attempt examine the dynamic causal relationships between carbon emissions, energy consumption, income and foreign trade in the case of Turkey using the time-series data by using the bounds testing to co integration procedure. The results indicate exist two forms of long-run relationships between the variables. Income is the most significant variable in explaining the carbon emissions in Turkey which is followed by energy consumption and foreign trade. Using time series data from 1980 to 2012 and VAR model explored the driving forces and reduction potentials of CO2 emissions in China's transport sector. The results show that energy efficiency plays a dominant role in decreasing CO2 emissions[23]. The amount of CO_2 emission from iron and steel production was calculated using the 2006 Inter govern-mental Panel on Climate Change (IPCC) guidelines in the boundary of production process[24]. Autoregressive Distributed Lag (ARDL) methodology and Granger causality test based on Vector Error-Correction Model (VECM) has been used to conduct the analysis the cointegration and causal relationship between economic growth, carbon dioxide (CO2) emissions and energy consumption in selected Association of Southeast Asian Nations (ASEAN) countries[25]. Promtida and Pichaya[26] has assessed CO2 reduction potential with respect to only energy emissions, which contributed the remaining 88 percent of the total emissions. The results shows that majority sources of CO2 emissions were energy consumption, encompassing onsite fuel combustion and generation of consumed electricity. The Logarithmic Mean Divisia Index has been computed analyses the sources of the change of energy intensity of the manufacturing industries in Thailand during the period (1991e2011) using the decomposition method and findings that need to balance industrial restructuring policies with efforts to reduce energy intensity for a sustainable economic development[27]. rigorous evidence-based economic measurement and analysis of the trade-off between CO2 emissions and economic growth for credible climate change policies are still limited globally. To improve analysis, Tran and Kitti[28] has develops a new "top down" endogenous growth-CO2 emission multi-equation model with an endogenous Kuznets environmental curve to provide robust empirical findings on the trade-off, its implications for climate change mitigation policy and credible national responses. Effects of energy intensive input utilization and farm technologies are directly associated especially with farm economic and atmospheric issues. Peeyush , Chakkrapong and Vilas[29] presents the energy input–output analyses of different agricultural activities and fresh pond-culture (polyculture), for which data were collected from 46 rainfed integrated agricultural production systems and reveals that majority energy input consumption for all productions are indicated by fossil fuel (diesel oil) as fresh pond-culture depended on fish feed. To verify empirically the impact of various factors on energy consumption in three ASEAN countries namely Indonesia, Malaysia and Thailand over the period 1980 to 2012, sundry appropriate diagnostic tests for checking time series data, the method of least square as an analytical technique has been used for parameters estimation. The findings validate that FDI inflows, economic growth, trade openness and human development index have positive and statistically significant impacts on energy consumption[30]. the Asia Pacific Integrated Model (AIM/Enduse) was applied to analyse impacts of CO2 reduction targets on Thailand's power sector and to determine equivalent carbon taxation, the cost optimization shows that when the reduction target is at 60% and a carbon tax of $200/tCO2, CCS technology is selected[31]. Using a panel cointegration technique for the period between 1980 and 2007 to analyze the impact of both economic growth and financial development on environmental degradation, the results support the Environmental Kuznets Curve (EKC) hypothesis. The causality results indicate that there exists strong bidirectional causality between emissions and FDI and unidirectional strong causality running from output to FDI[32]. Usama and Che[33] has investigated the impact of energy consumption on the economic and financial development in 19 countries by using panel model. The results show that energy consumption enables these countries to achieve high economic and financial development. Md. Sharrif H[34] has analysed the dynamic causal relationships between carbon dioxide emissions, energy consumption, economic growth, trade openness and urbanization for newly industrialized countries (NIC) by using the time series data. The result shows that over time higher energy consumption in the newly industrialized countries gives rise to more carbon dioxide emissions as a result our environment will be polluted more. In EKC analyses, the relationship between environmental degradation and income is usually expressed as a quadratic function. Jean and Duane[35] has analysed models to illustrate the importance of prices in these models and then includes prices in an econometric EKC framework testing energy:income and CO2:income relationships and find that income is no longer the most relevant indicator of environmental quality or energy demand. The implied inverted-U relationship between environmental degradation and economic growth came to be known as the "environmental Kuznets curve," by analogy with the income inequality relationship postulated by Kuznets[36]. Improvements in some measures of air and water quality can accompany rising per capita income, as illustrated by the so-called environmental Kuznets curve. Mariano and James[37] hypothesize that a more equitable distribution of power contributes to these outcomes, by enhancing the influence on policy of the costs of pollution. EKC inverted U relationship can be explained by trade and specifically the migration or displacement of 'dirty' industries from the developed regions to the developing regions[37]. Matthew[38] has contributed to the EKC relationship and finding that this is the case for the basic industries, but little widespread evidence for the manufacturing sector as a whole.

4. The Methodology and data

Data sources and Model specification

This study focuses on the relationship between per capita CO_2 emissions (CO_{2t}), per capita energy consumption (kg of oil equivalent), per capita real FDI(measured in US dollar), per capita real GDP_t(measured in US dollar) and the square of per capita real GDP (GDP_t^2). This study uses the annual data from 1988 to 2014 extracted from World Development Indicators (WDI) database and Ministry of Industry, Thailand. All the variables in the model are transformed into logarithmic and differential form to avoid possible heteroscedasticity and multicollinearity problem (see [39,40]). The EKC hypothesis notes that there have relationship between CO_2 emissions and incomes in form of non-linear quadratic. EKC inverted-U relationship can be explained by trade and specifically the migration or displacement of 'dirty' industries from the developed regions to the developing regions[37]. The earliest EKCs were simple quadratic functions of the levels of income. But, economic activity inevitably implies the use of resources and, by the laws of thermodynamics, use of resources inevitably implies the production of waste. A logarithmic dependent variable will impose this restriction. Grossman and Krueger [39] has used a cubic EKC in levels and found an N-shape EKC. This might just be a polynomial approximation to a logarithmic curve. Grossman and Krueger[40] is the first study that discovered a quadratic relationship between per capita income and pollutions. They documented that this quadratic relationship can be explained by three factors: scale, composition and technical effects. This relationship is known as the EKC because the idea of an inverted-U shape relationship originated from Kuznet[41]. From Previous studies have noted that apart from per capita income, energy consumption and FDI are two important determinants of CO_2 emissions (e.g. refs. [22, 30, 32]). Therefore, the relationship between CO_2 emissions, energy consumption, income, and FDI is given below:

$$\ln CO_{2t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP_t^2 + \beta_3 \ln EC_t + \beta_4 \ln FDI_t + \varepsilon_t \quad (1)$$

where CO_{2t} is per capita CO_2 emissions, GDP_t is per capita real GDP, GDP_t^2 is squared of per capita real GDP, EC_t is per capita energy consumption and FDI_t is per capita real FDI. Ln denotes the natural logarithm and ε_t is the disturbance term. The parameters $\beta_1, \beta_2, \beta_3$ and β_4 are the long-run elasticities of CO_2 emissions with respect to $\ln GDP_t$, $\ln GDP_t^2$, $\ln EC_t$ and $\ln FDI_t$, respectively. According to EKC hypothesis from Kuznet[41], the sign of β_1 is expected to be positive, the sign of β_2 is expected to be negative. If β_2 is statistically insignificance, it indicates that the EKC hypothesis is not valid because pollution-income is just a monotonic relationship.

Stationary test

The vast majority of econometric models require that economic time series are stationary. Since most economic variables are nonstationary sequence, a differencing method is commonly used to eliminate the non-stationary trend in order to build a reasonable model. Before establishing the model for analysis, it is necessary to implement a stationary test. The standard method of checking sequence stationary is the unit root test. ADF (Augmented Dickey Fuller) test, KPSS (Kwiatkowski Phillips Schmidt Shin) test, and DFGLS (Dickey Fuller GLS) test are the three most commonly used test methods.

Multivariate Johansen test

Base on the empirical model presented in equation (1), there are more than two variables. Hence, we employ the multivariate cointegration technique from Johansen[42]. The Johansen cointegration can be conducted by estimate of following VECM (vector error-correction model)[43].

$$\Delta X_t = \begin{bmatrix} \Delta \ln CO_{2t} \\ \Delta \ln GDP_t \\ \Delta GDP_t^2 \\ \Delta \ln EC_t \\ \Delta FDI_t \end{bmatrix} = \emptyset W_t + \Pi \begin{bmatrix} \ln CO_{2t-1} \\ \ln GDP_{t-1} \\ GDP_{t-1}^2 \\ \ln EC_{t-1} \\ FDI_{t-1} \end{bmatrix} + \tau_1 \begin{bmatrix} \Delta \ln CO_{2t-1} \\ \Delta \ln GDP_{t-1} \\ \Delta GDP_{t-1}^2 \\ \Delta \ln EC_{t-1} \\ \Delta FDI_{t-1} \end{bmatrix} + \cdots + \tau_k \begin{bmatrix} \Delta \ln CO_{2t-k} \\ \Delta \ln GDP_{t-k} \\ \Delta GDP_{t-k}^2 \\ \Delta \ln EC_{t-k} \\ \Delta FDI_{t-k} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix} \quad (2)$$

where Δ is the first difference operator $(X_t - X_{t-1})$,Wt is a vector of deterministic components (i.e. constant and trend) and $\emptyset$ is a matrix of parameters for Wt. ε_{it} are the normally distrusted and serially uncorrelated disturbances term. k is the lag length in the VECM system. All long-run information about the relationship between X_t variables is inside the 5x5 impact matrix of Π. If the variables in X_t are integrated of order one, $I(1)$ the cointegrating rank, r, is given by the rank of $\Pi = \alpha\beta'$ where α is the matrix of parameters representing the speed of convergence to the long-run equilibrium and β is the matrix of the cointegrating vector.

Granger causality test

If the variables are cointegrated, we will conduct the Granger causality test using the VECM system in order to avoid the long-run causation information [44]. However, if the variables are not cointegrated, the one period lagged error-correction term(ε_{t-1}) will be excluded from the VECM system. In this case, it is just the first difference VAR (vector autoregressive) system. Assuming that the variables are cointegrated, we estimate the following VECM system to investigate the direction of causality.

$$\begin{bmatrix} \Delta \ln CO_{2t} \\ \Delta \ln GDP_t \\ \Delta GDP_t^2 \\ \Delta \ln EC_t \\ \Delta FDI_t \end{bmatrix} = \Omega_0 + \Omega_1 \begin{bmatrix} \Delta \ln CO_{2_{t-1}} \\ \Delta \ln GDP_{2_{t-1}} \\ \Delta GDP_{2_{t-1}}^2 \\ \Delta \ln EC_{2_{t-1}} \\ \Delta FDI_{2_{t-1}} \end{bmatrix} + \cdots + \Omega_k \begin{bmatrix} \Delta \ln CO_{2_{t-k}} \\ \Delta \ln GDP_{2_{t-k}} \\ \Delta GDP_{2_{t-k}}^2 \\ \Delta \ln EC_{2_{t-k}} \\ \Delta FDI_{2_{t-k}} \end{bmatrix} + \psi_{\varepsilon_{t-1}} + \begin{bmatrix} \upsilon_{1t} \\ \upsilon_{2t} \\ \upsilon_{3t} \\ \upsilon_{4t} \\ \upsilon_{5t} \end{bmatrix} \quad (3)$$

Here, Ω is 5x5 matrix of parameters of endogenous variables(i.e. $\Delta \ln CO_2$,$\Delta \ln GDP_t$, $\Delta \ln GDP_t^2$, $\Delta \ln EC_t$, and $\Delta \ln FDI_t$) in the VECM system, Ψ is a matrix of parameter for one period lagged error correction term, ε_{t-1} while υ_{it} are the disturbances term. If the variables are cointegrated, there are short-run and long-run causality that can be tested through the VECM system. From equation (3), $\Omega_k \neq 0\ \forall_k$ implies the presence of short-run causality, while $\Omega_k \neq 0\ \forall_k$ and $\Psi \neq 0$ indicate the presence of long-run causality.

Table 1 UNIT ROOT TEST RESULT-ADF

Variables	ADF statistics
$lnco_2$	-2.750
$\Delta lnco_2$	-3.119**
lnec	-2.540
Δlnec	-5.511***
lngdp	-1.536
$\Delta \ln GDP_t$	-3.154**
$\ln GDP_t^2$	-1.252
$\Delta \ln GDP_t^2$	-3.205**
lnfdi	-2.160
Δlnfdi	-5.958***

Note: The asterisks ***, ** and * denoted the statistical significance level at 1%, 5% and 10%, respectively.

5. Empirical results

Testing the degree of integration

Before conducting analysis, the time series should be changed to stationary sequence (Box and Jenkins, [45]). Otherwise, the estimated parameters will be biased, making it difficult to effectively explain the economic reality. The usual method of changing non-stationary time series into a stationary series is first order differencing (Xu and Moon, [46]). The standard unit root tests (ADF, DFGLS and KPSS tests) are used to test whether these variables have unit root. The SC (Schwarz information criterion) is applied to choose the optimal lag structure. The results of the unit root test for all the variables are presented in Table 1.

The optimal lag order analysis

In order to ensure that the parameters in model have a strong explanatory power, there must be a balance between the lag period and the degrees of freedom. With respect to the lag structure for the VAR model, the proper selection of lag period is very important since long lag structures can reduce the autocorrelation of the error term, and may results in the model being inefficient. Looking at table 2 in this paper it can be seen that we choose a lag of 3 as dictated by the Logarithmic likelihood ratio (LogL), AIC, SC, sequential modified LR test statistic (LR), FPE (Final prediction error), and HQ (Hannan-Quinn) information criterion (Table 2).

Table 2 LAG SELECTION ORDER CRITERIA

Lag	LogL	LR	FPE	AIC	HQIC	SBIC
0	46.5301	NA	2.5e-08	-3.32241	-3.2548	-3.07863
1	183.398	273.74	3.4e-12	-12.2719	-11.8662	-10.8092*
2	209.778	52.76	4.0e-12	-12.3823	-11.6385	-9.70073
3	255.461	91.365*	1.8e-12	-14.0368*	-12.955*	-10.1364
4	NA	NA	-5.2e-25*	NA	NA	NA

Cointegration results

As the results of the ADF test in table 1 indicate that the variables under investigation are *I*(1), we can proceed to examine the presence of any cointegrating relationship with the multivariate Johansen cointegration test. However, determination of cointegration rank of Johansen cointegration test is very sensitive to the choice of lag length[47,48]. Therefore, we place special attention to these three issues. To choose an optimal lag length, we use various system-wise methods such as AIC, SBC, FPE, HQ and LR test. Looking at table 2 we can seen that the information-based criteria (i.e. AIC, SBC, FPE and HQ) and the LR test results in Table 2 consistently indicate that the lag length of three year is the best.

Table 3 reports the result of Johansen cointegration test. Regardless of adjusted or unadjusted LR statistics of trace and maximum eigenvalue tests[49], both LR statistics reject the null hypothesis of no cointegration rank at the 5 per cent significance level. Nevertheless, at the same significance level, they cannot reject the null hypothesis of more than one cointegration rank.Moreover, Trace test indicates 1 cointegrating equation at 5% significance level. Therefore, Johansen cointegration results recommend that there is one cointegration rank among the four variables.

Granger causality results

As we can seen from section 5.3 that the variables cointegrated, computation of short- and long-run elasticities with reference to the CO_2 emissions is required to examine the validity of the EKC hypothesis in Thailand. Table 4A shows the normalised cointegrating vector (i.e. long-run elasticities), while Table 4B reports the short-run elasticities estimates by ECM (error-correction model) and Table 4C reports the diagnostic tests of ECM. In the long-run, we find that all variables are statistically significance at the 1 per cent level. The long-run elasticity of CO_2 emissions with reference to energy consumption is 0.550, meaning that a 1 per cent increase in per capita energy consumption is associated with a 0.550 per cent increase in per capita CO2 emissions. The long-run elasticitiy of CO_2 emissions with reference to economic growth is 10.397 $\ln GDP_t$. The statistical significance of $\ln GDP_t^2$ indicates that there is a quadratic relationship between CO2 emissions and economic growth (GDP). This result reveals that where the CO_2 emissions increase at the initial stage of economic growth, and decline thereafter. Meaning that the EKC hypothesis is valid in Thailand. This finding is contrary to Chandran[50] but corroborated by Ang[8], Halicioglu[51] and Selden and Song[52], who have also found an inverted-U shape relationship between CO2 emissions and economic growth. Chandran and Chor[53] attempts to validate the Environmental Kuznets Curve(EKC) hypothesis. Their results reveal that the inverted U-shape EKC hypothesis is not applicable to the ASEAN-5 economies, especially in Indonesia, Malaysia and Thailand.

Table 3 JOHANSAN COINTEGRATION TEST

Cointegration Test Base on λ_{trace}			
H_0	H_1	Trace statistic	5% critical value
r=0	r>1	94.3130**	68.52
r=1	r>2	46.2486	47.21
r=2	r>3	24.9617	29.68
r=3	r>4	7.7828	15.41
r=4	r>5	0.0008	3.76
Cointegration Test Base on λ_{max}			
H0	H1	Eigenvalue	5% critical value
r=0	r=1	44.2430**	34.81
r=1	r=2	18.4318	29.20
r=2	r=3	13.4073	21.59
r=3	r=4	7.7828	12.83
r=4	r=5	0.0003	3.76

Note: The asterisk ** denote statistical significance at 5 percent levels. r denoted Rank.

The elasticity of CO2 emissions with reference to FDI is 0.168. This indicates that a 1 percent increase in per capita real FDI will lead to 0.168 percent increase in per capita CO2 emissions. Evidently, the results indicates that the influx of FDI is not good for the environment and increases pollution. On other word, the results indicates that transferring technologies and production techniques from developed countries to Thailand is not friendly for the environment and increases pollution. Thus, we accept the pollution haven hypothesis in Thailand. This is in line with the finding of Acharyya[54] and Merican et al.[55] but contrary to Chor and Bee[56]. Merican[55] has conducted time-series analyses, employing the Autoregressive Distributive Lag (ARDL) technique. The result suggest that FDI adds to pollution in Malaysia, Thailand.

Table 4A NORMALISED COINTEGRATION COEFFICIENT-LONG RUN ELASTICITIES

lnco2	Coefficient	t	p-value
constant	64.99676		
lnec	0.5504819	4.45***	0.000
lnGDP	10.39712	6.41***	0.000
lnGDP2	-0.3993563	-6.18***	0.000
lnFDI	0.1678003	3.62***	0.000

The one period lagged error-correction term(ε_{t-1}) derived from the cointegrating vector is statistically significance at the 5 per cent level. Base on the size of error-correction term (ε_{t-1}), if the system is exposed to shock, the speed of convergence is considered fast.

Table 4B VECTOR ERROR CORRECTION MODEL(VECM)-SHORTRUN ELESTICITIES

Variables	Coefficient	t	p-value
constant	0.1321228	0.64	0.523
Δlnec	-2.646177	-2.57**	0.010
$\Delta\Delta$lnEC	0.4896707	0.51	0.609
$\Delta \ln GDP_t$	-1.795585	-0.27	0.784
$\Delta\Delta \ln GDP_t$	11.36236	1.96**	0.050
ΔGDP_t^2	0.0897922	0.32	0.745
$\Delta\Delta GDP_t^2$	-0.4789731	-1.97**	0.049
ΔlnFDI	0.0277374	0.42	0.675
$\Delta\Delta$lnFDI	-0.0522465	-1.01	0.310
(ε_{t-1})	-0.042	-1.99**	0.047

Table 4C DIAGNOSTIC TESTS

R^2	0.9950
Adjusted- R^2	0.9941.
F-statistic	1187.64 (0.0000).
χ^2 Normality test	5.286(0.87130).
χ^2 Serial correlation test	[1] 28.7625(0.27397) [2] 19.3725(0.77892).

Note: *** and ** denoted the statistical significance at the 1 and 5 percent levels, respectively. [ ] is the order of diagnostic test, whereas ( ) is the p-value.

Although GDP and FDI are statistically insignificance on CO_2 and the magnitude of $\Delta \ln GDP_t$ and ΔGDP_t^2 are larger in the short-run, but the sign of these variables confirm the existence of an inverted-U shaped relationship between CO_2 emission and economic growth(i.e. EKC hypothesis). The impact of FDI on CO_2 emission is 0.028 in the short-run, but it is statistically insignificant. For this insignificance magnitude, given the fact that it is hard for the recipient country to immediately learn and adapt to the advanced technology and new production techniques because it takes time to learn. Therefore, it is not surprising to obtain such insignificance relationship in the short-run.

Ultimately, the results of diagnostic test has been presented on table 4C. Diagnostic test has been performed on the VECM and the model passed all diagnostics. We find that serials are normally distributed. Adjusted-R^2 was 0.9941, this indicated that there is very high of goodness of fit. F-statistic was 1187.64 and significant at 1 percent level, this value indicated that all the variables jointly affect CO2. We find that the residuals are normally distributed and serially uncorrelated up to order two.

Table 5 RESULT OF GRANGER CAUSALITY TEST

Null Hypothesis	χ^2 statistics (p-value)
EC does not granger cause CO2	7.20 (0.0274)**
GDP does not granger cause CO2	3.94 (0.1392)
FDI does not granger cause CO2	2.42 (0.2979)
CO2 does not granger cause EC	6.75 (0.0343)**
GDP does not granger cause EC	1.37 (0.5030)
FDI does not granger cause EC	2.91 (0.2339)
CO2 does not granger cause GDP	5.48 (0.0645)*
EC does not granger cause GDP	6.84 (0.0327)**
FDI does not granger cause GDP	4.43 (0.1094)
CO2 does not granger cause FDI	11.06 (0.0040)***
EC does not granger cause FDI	5.01 (0.0818)*
GDP does not granger cause FDI	3.27 (0.1953)

Note: ***, ** and * denoted the statistical significance at the 1, 5 and 10 percent levels, respectively.

Table 5 shows the results of analysis short-run causal effect. We observed some unidirectional Granger causalities; (1) running from energy consumption to FDI, (2) running from economic growth to energy consumption. In long-run causality, we find that in the short-run FDI and CO_2 emission are bidirectional Granger causality. Apart from these, our findings reveal that in the short-run GDP and FDI do not Granger cause each other(i.e. neutral causality).

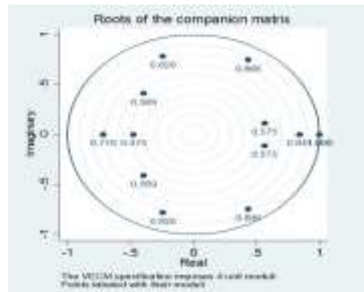


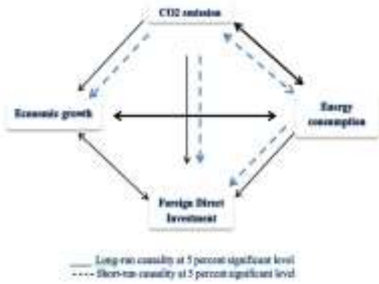
Fig. 2. VAR roots of characteristic polynomial.
Note: blue dots indicated characteristic root

From these findings, several conclusions could be made, first economic growth and energy consumption are the main determinant of CO_2 in Thailand. Thus change in anyone or all of these variables will affect the level of pollution in Thailand, Second FDI is not crucial catalyst of growth in Thailand as our Granger causality results indicate that FDI does not Granger causality GDP, EC and CO_2 in the short-run.

Looking at Fig.2, Analysing characteristic roots in Fig.2 shows that all the characteristic roots are less than 1 and lies inside the unit circle. It indicates that the VAR(3) model and the parameter of Eq. (1) satisfies the stability condition. So the results of the Eq. (1) derived from the VAR(3) are valid.

6. Conclusion and policy recommendations

We used the method of Johansen cointegration and Granger causality to investigated the dynamic relationship between CO_2 emission, energy consumption, economic growth and FDI in Thailand based on EKC hypothesis. The result of Johansen between CO_2 emissions, energy consumption, economic growth and FDI in Thailand The long-run elasticity of CO_2 emissions with regard to energy consumption is computed as 0.550. Moreover, the elasticity of CO_2 emissions in regard to income in the long-run is shown to be 10.3971 and the sign of $\Delta\Delta GDP_t^2$ is negative, which indicates a quadratic relationship between CO_2 emissions and economic growth. However, the FDI is found to be positively affecting CO_2 emissions in the long-run. Furthermore, the study also explored the causal relationship between the variables using the VECM Granger causality models(Fig. 2). The results indicate that Granger causality runs in both directions between CO_2 emissions and energy consumption, both in short- and long-run. Besides, energy consumption is found to Granger causes CO_2 emissions in the short-run and long-run. However, FDI is not found to Granger cause energy consumption and economic growth in the short-run. The empirical evidence showed that energy consumption increases carbon emissions and economic growth is a major contributor to CO_2 emissions.



Figs. 3. Summary of Long-run and Short-run Granger causality.

From the results and observations that we found in previous sub sectors, there are several recommendations can be shared based on this study to help policy makers to achieve sustainable economic development in Thailand. Thailand policy makers may need to take into consideration in order to draft effective investment policy and environmental policies to fight global warming while stimulating economic growth at the same time. Despite the rigid findings such as high economic growth and energy consumption will cause higher CO_2 emissions in the long-run and energy consumption Granger-causes CO_2 in both the short-run and long-run. The empirical showed that economic growth condenses carbon emissions and inverted-U shaped relationship is also confirmed between economic growth and carbon emissions. This validates the contribution of economic sector to improve the quality of environment. The result simply that CO_2 emissions can be reduced at the cost of efficient technology. Energy efficient technologies should be encouraged to enhance domestic production with the help of investment sector and import environment friendly technology from advanced countries. Again, investment sector must fix its focus on those firms which adopt environment friendly technologies and encourage the firms to use more energy efficient technology for production purpose and hence to save environment from degradation. Given the finding that FDI inflows are not better positioned to improve and uphold higher environmental standards in Thailand's economy. From policy perspective, Thailand should does policy adoption. To adopt policy such as green energy policy and green FDI policy to achieve green growth. These green policy can provides developing economics in country access to such environmental friendly technologies and thus plays a crucial and effective role in conveying clean technology and low pollution technologies to developing countries. In addition, investors would concerned about the short and long-term impacts on climate change and concern that those clean energy policies are essentially needed to avoid calamitous blow. First of all, Thailand policy makers should focus on technology development which can shifting away from carbon intensive infrastructures can reduce costs and increase productivity which lead to a substantial acceleration in economic growth and yield benefit environmental. Besides, Informants who do environmental regulations and enforcement of environmental responsibility for eco-efficiency should be imposed to encourage the adoption of clean technologies which are well developed and established in advanced nations. In summary, it is crucial that the Thailand government while offering an inductive investment environment to attract FDI such ass Ministry of Industry, set proper policies on environmental planning and transfer of green technologies to ascertain the commitment of investors to environmental responsibility, energy and wider sustainability in the country. Drafting policies which promote the concept of green energy and green FDI to fight global warming and moderate the climate change phenomenon will provide regulatory certainty that in turn will influence inward FDI and accelerate economic growth in Thailand.

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