Energy consumption, emissions and economic growth in an oil producing country

Ismail, Mohd Adib and Mawar, Murni Yunus

Universiti Kebangsaan Malaysia, International Islamic University College of Selangor

February 2012

Energy consumption, emissions and economic growth in an oil producing country

Mohd Adib Ismail[a,1] , Mawar Murni Yunus[b,2]

[a]School of Economics, Universiti Kebangsaan Malaysia, 43650 UKM Bangi, Selangor, Malaysia

[b]Faculty of Management and Muamalah, International Islamic University College of Selangor, 43000 Kajang, Selangor, Malaysia

Abstract

This study is aimed to examine the causal relationship between economic growth, energy consumption and emissions in Bahrain. As required by the Kyoto Protocol where Bahrain has ratified in 2006, it is to reduce greenhouse gas (GHG) emissions. This study uses Toda and Yamamoto's (1995) approach to investigate the relationship. The finding regarding the relationship is crucial as it will justify appropriate steps should be taken by Bahrain to reduce emissions without affecting her national output. Using annual data for a period from 1980 to 2007, this study finds that there are unidirectional relationship between output, capital, energy use, labor and emissions. It also finds that there is causality running from output to capital, energy use and emissions, but not vice versa. Therefore, this study suggests emissions cut cannot be simply taken without sacrificing the economy. On the other hand, replacing capitals with greener capitals is the best choice as it reduces emissions through energy efficiency and less GHG emissions.

Keywords: Economic growth; emission; greenhouse gas; energy; Bahrain

JEL classification: O40; Q40; Q43; Q50

1. Introduction

The energy and economic growth has been widely studied by economists. Using various econometric approaches, the studies utilized contemporary issues happened during the oil shock period in 1970s and after the adoption of the Kyoto Protocol in late 1990s. Payne (2010) and Ozturk (2010) review the studies. Payne and Ozturk show that majority of the studies focus on causal relationship between energy consumption and economic growth. However, the studies find no conclusive finding regarding the relationship. Payne argues that this failure is due to omitted variable bias as described in Lutkepohl (1982). Then, other factors such as labor and capital were included in later studies. Secondly, Payne also points out that lacks of empirical result interpretation cause lacking in policy recommendation in the case of statistical signs and their magnitudes of coefficients. Ozturk (2010), on the other

[1] Corresponding author. Tel.: +603-8921 3301. E-mail: mohadis@ukm.my.
[2] Tel.: +603-8925 4251. Fax.: +603-8925 4472. E-mail: mawarmurni@kuis.edu.my.

hand, argues that the diverse relationship was due to different methodologies and datasets used that embed with different specific characteristics.

Payne (2010) and Ozturk (2010) concluded that there are three types of energy-economic growth relationship. They are, (i) unidirectional causality running from energy to economic growth (growth hypothesis) or from economic growth to energy (reservation hypothesis), (ii) bi-directional causality between energy and economic growth (feedback hypothesis), and (iii) no-causal relationship between energy and economic growth (neutral hypothesis). For the growth and reservation hypotheses the signs of relationship can be positive or negative, while the feedback hypothesis has only positive sign.

The concern about climate change and the adoption of Kyoto Protocol in late 1997 have attracted economists to study further the energy-economic growth relationship with respect to steps to alleviate the greenhouse gas (GHG) effects to be taken by the signatory parties. To address this issue, the standard bivariate or multivariate model is modified to include GHG indicators. Kyoto Protocol outlines six GHGs, namely, carbon dioxide (CO2), methane (CH4), nitrous oxide (N20), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). Most studies use CO2 as the indicator of GHG emissions as it constitutes major part of the emissions and its data is annually observed and easily available.

We can categorize this type of studies into two groups. This first group adopts environmental Kuznets curve (EKC) hypothesis. This hypothesis argues that the environment and economic growth has an inverted U-shaped curve. This non-linear relationship shows that environmental degradation is positively associated with economic growth at certain stages of economy, particularly early stages of economic development. However, once the economy grows beyond a certain threshold, the relationship turns to be negative. In the latter situation, the environmental conservation has positive correlation with economic growth whereas the environmental degradation has negative correlation with the economy. Stern (2004), Dinda (2004), Aslanidis (2009) and Kijima et al. (2010) provide reviews of the EKC studies. Stern (2004) concludes that previous EKC studies were not robust as they failed to give clear finding on the inverted U-shaped relationship between environment and economic growth as income rises. Dinda (2004) also concludes that previous studies did not provide concrete finding when the negative correlation between environmental degradation and economic growth starts. Therefore, Dinda suggests that, among others, new economic modeling is needed to reflect the important feedback relationship between economic growth and environment. A current survey by Kijima et al. (2010) also shows the similar conclusion on EKC literatures. In this case, Bo (2011) suggests careful selection of indicators in order to examine the environment-economic growth relationship since the previous EKC model use simplified modeling.

Due to the EKC failure, current studies utilize a vector autoregressive (VAR) model to study the environment-economic growth. This approach constitutes the second group of environment-economic growth literature. This model allows endogenous characteristics of variables included. Rather than employing a bivariate model, a multivariate model is preferred to avoid omission variable bias problem. Thus, the multivariate energy-economic growth is modified to insert environment indicators. It differs with the previous energy-economic growth studies as the environment effects are interpreted explicitly in the model. Sotyas et al. (2007), Sotyas and Sari (2009) and Zhang and Cheng (2009) are studies that use the approach. Sotyas et al. examine energy, economic growth and carbon emission in the United States (US) finds that income does not Granger cause carbon emission in the long run. Similar finding is also found by Zhang and Cheng in China and Sotyas and Sari in Turkey. This finding indicates that environmental conservation can be implemented without hurting economic growth.

There are limited number of studies that examine the environment and economic growth of an oil producing country specifically the country in the middle-east. To our survey, Al-Iriani (2006) has studied economic growth and energy consumption in the Cooperation Council for the Arab States of the Gulf (GCC) countries. Al-Iriani used a pooled data to examine the relationship. Though this method may correct specific country effects bias, it fails to recognize specific characteristics of a country in GCC such as sectoral dependence of economy to oil industry. Therefore, focusing on a country's data may provide better economic interpretation. Similarly, Mehrara (2007) used panel cointegration approach to study the relationship between commercial energy consumption and economic growth. Using a panel bivariate model of 11 oil exporting countries including Bahrain, Mehrara finds similar result where economic growth granger cause energy consumption. Chontanawat et al. (2008), on the other hand, find no causality between energy and economic growth in Bahrain. Chontanawat et al.'s result may subject to omitted variable bias since they used a bivariate model. Overall, to our knowledge there is no study to incorporate both energy and economic growth together with emission variable in an oil producing country.

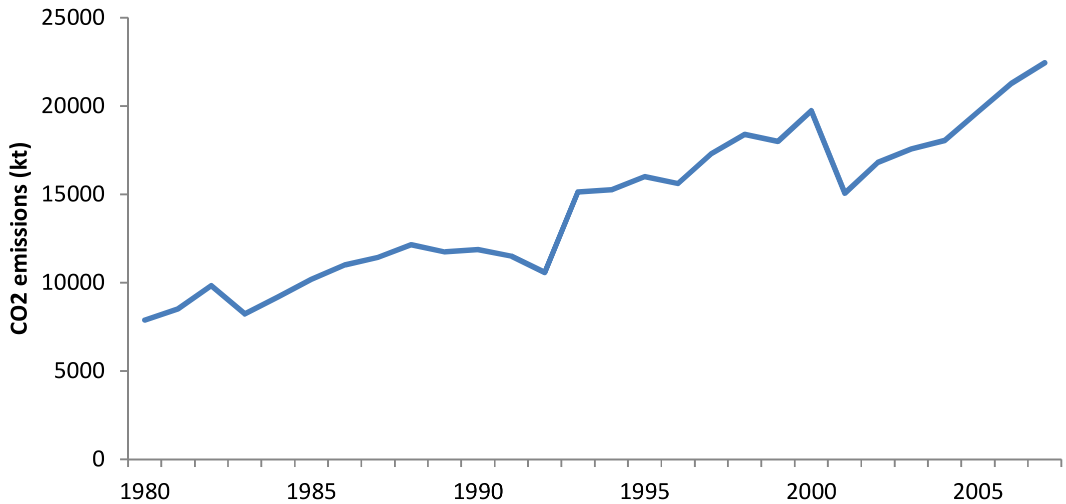
As a result to fill the gap, this study is aimed to study the relationship between economic growth, energy consumption and emissions of a highly dependent country on oil production industry. We select Bahrain as she is one of oil exporting countries where her major sectors center around exploration and production fossil fuels and manufacturing their related byproducts. Thanks to a high world oil price, crude oil constituted 25 percent of Bahrain's nominal gross domestic product (GDP). Oil also constituted major components of export. Therefore, oil income is very important for Bahrain not only to finance imports of goods, but also to maintain its external balance and to accumulate reserve for financing its exchange rate pegging system to US Dollar (Board 2008). Due to this dependence, CO2 emission has been increasing from year to year (see Figure 1). Realizing this problem, National Oil and Gas Authority (NOGA) of Bahrain outlined strategic objective to cater this issue. Under its second strategic objective NOGA outlined its petroleum legislations and policies to participate in steps to promote safety and environmental protection with giving preference to steps in eliminating pollutants and toxic gas emissions. In doing so, Bahrain will cooperate with other GCC countries and domestic companies to carry out environmental studies and assessments (Authority 2010). In addition, Bahrain ratified Kyoto Protocol at 31 January 2006 and entered into force at early May in the same year. According to the protocol, the signatory parties need to limit their greenhouse gas (GHG) emissions and promote sustainable development (UNFCCC 1998). As part of the initiatives to cut carbon emissions related to oil and gas industry, NOGA collaborated with Masdar of Abu Dhabi, UAE to implement environmentally sustainable projects (Baxter 2009).

Using annual data from 1980 to 2007, this study employs Toda and Yamamoto's (1995) approach to examine environment-energy-economic growth relationship. This study is crucial because as it may provide policy implications on how to reduce emission without cutting the oil production which is the main source of the income of Bahrain. This study finds there are unidirectional relationships running from output to capital, energy use and emissions, from capital to energy use and emissions, from energy use to emissions, and, from labour to emissions. Based on this finding, this study does not recommend a simply GHG emissions reduction through energy cut because it will negatively affect the economy. Hence, other options such as replacing existing capitals with greener capitals is the best choice as it will reduces emissions through energy efficiency.

The remaining of this study is organized as follow. In the next section we discuss the methodology used in this study. After that, we discuss the estimation results and, finally we conclude.

2. Methodology

The application of VAR model using Toda and Yamamoto (1995) (T-Y afterwards) has some advantages. According to Payne (2010), T-Y is good with small but typical size used in time series studies. Yamada and Toda (1998) has compared the approach with error correction model (ECM) of Johansen (1988) and of Johansen (1991), and fully modified VAR (FM-VAR) of Phillips (1995). They find their model outperforms other two models for a sample size that is typical in a time series study. They also find that FM-VAR is very sensitive to values of parameters chosen in the data generating process (DGP) and ECM is dependent on selection of cointegrating rank at high accuracy rate. Next, T-Y approach can also be performed irrespective whether the variables are stationary or not, and cointegrated or not. Therefore, any pretest for unit root is unnecessary, though it is informative, to be done before proceeding the T-Y approach. Sotyas et al. (2007), Sotyas and Sari (2009) and Zhang and Cheng (2009) use this approach in their studies. Following their approach, we outline T-Y procedures as follows. Unit root tests are applied to find the highest order of integration for each variable used. Certain criteria are used, for instance minimum Schwarz information criterion to select the lag order in unit root tests. Rejection of null hypothesis determines the order of integration and stationarity. Let say we find the order is d. Then, a VAR model is estimated to find its optimal lag length. The minimum values of final prediction error (FPE), Akaike's information criterion (AIC), Hannan and Quinn information criterion (HQIC) and Schwarz's Bayesian information criterion (SBIC) are used to determine the lag length. To ensure stability, normality and no-autocorrelation of residuals, respective post VAR tests are done. Once, all three tests are satisfied, we can determine the lag length. Let say the lag of VAR is p. Next, a new VAR($p+d$) can be estimated. Again, another post VAR tests are done. Lastly, we test for Granger non-causality. In order to do that, a Wald test is done on p lag order only, not on all lags. Rejection of the null indicates Granger causality running from a variable to another variable. The causality information, however, contains both short and long run relationship. To decompose the information, an impulse response function (IRF) is used to see whether the relationship last perpetually or just temporarily.

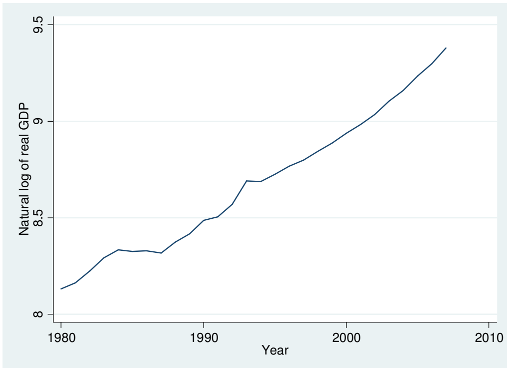


Source: World Bank (2011), World Development Indicators.

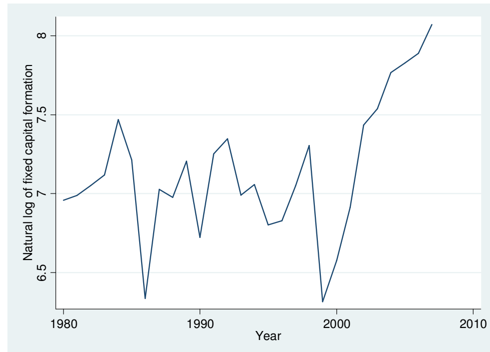
Figure 1 CO2 emissions (kt) in Bahrain

3. Sources of data

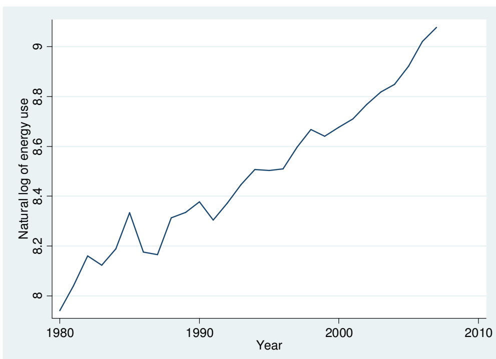
There are five variable used in the analysis, namely, output or real gross domestic product (*Y*), energy usage (*E*), emissions (*C*), labour (*L*) and capital (*K*). *Y*, *K* and *L* are taken from World Economic Outlook (2011) (WEO), International Monetary Fund. *E* and *C* are taken from World Bank (2011) Development Indicators. All data are annual data from 1980 to 2007. Originally, *Y* is measured in US$ billion current prices, but we transform it into real terms using GDP deflator available from WEO. Energy usage is measured in kilo tons of oil equivalent. We used CO2 emission as the indicator of GHG emissions as it is observed annually and constitutes major part of emissions. This indicator is used by many previous researchers such as Sotyas et al. (2007), Ang (2008), Sotyas and Sari (2009), Zhang and Cheng (2009) and Hamit-Haggar (2012). We also use population as a proxy of labour as in Song et al. (2008). Besides, following Alexander (1994), the investment is used as a capital. Investment data was in percentage form of fraction of GDP. We multiply with real GDP to obtain real capital. All data are transformed into natural logarithm. Instead of using per capita data, we use total data. This is as argued in Friedl and Getzner (2003) and Sotyas et al. (2007), emission reduction required by the Kyoto Protocol is based on percentage of total reduction. Taking per capita will down scale the variable size which may cause estimation bias. All variables are plotted as in Figure 2. The variables exhibit trends. Furthermore, the capital clearly exhibits a stationarity process around a certain constant mean. However, to ensure the stationarity order of variables we run stationarity tests.



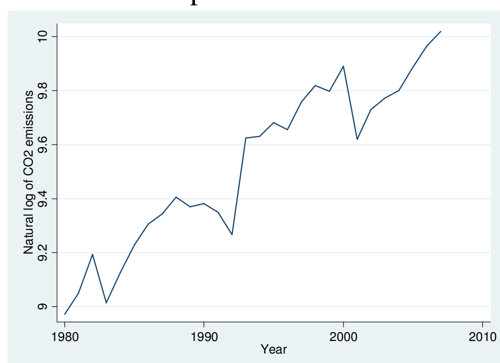
(a) Natural log of real GDP



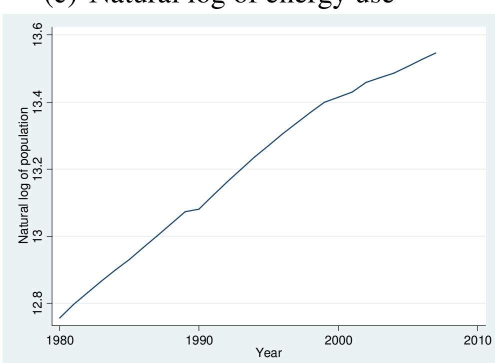
(b) Natural log investment as a proxy of fixed capital



(c) Natural log of energy use



(d) Natural log CO2 emissions



(e) Natural log of population as a proxy of labour

Figure 2 Trends of output, capital, energy use, emission and labor

Table 1 Traditional unit root tests results

		Dfuller	Pperron	Dfgls	Kpss
Levels					
Intercept only	Y	2.143	1.880	0.251(3)	0.676**(4)
	K	-0.279	-1.941	-0.925(1)	0.296(4)
	E	1.325	0.100	1.192(5)	0.686**(4)
	C	-1.016	-0.962	0.803(1)	0.665**(4)
	P	-1.748	-3.410**$^{\#+}$	-0.103(3)	0.669**(4)
Intercept and trend	Y	-1.611	-0.842	-0.841(1)	0.150**(4)
	K	-0.674	-2.448	-1.508(1)	0.131*(4)
	E	-0.716	-3.207$^{\#+}$	-1.717(5)	0.158**(1)
	C	-2.682	-3.544*$^{\#+}$	-2.276(1)	0.0905(3)
	P	-0.187	0.462	-0.482(1)	0.163**(4)
First differences					
Intercept only	Y	-1.922$^{\#}$	-4.205***$^{\#+}$	-2.694***(1)	0.315(3)
	K	-2.665*$^{\#}$	-7.001***$^{\#+}$	-3.693***(1)	0.199(4)
	E	-3.275***$^{\#+}$	-6.975***$^{\#+}$	-1.440(4)	0.146(4)
	C	-3.128**$^{\#}$	-7.510***$^{\#+}$	-3.367***(1)	0.072(3)
	P	-0.843	-3.135**$^{\#+}$	-1.501(1)	0.473**(4)
Intercept and trend	Y	-3.402*$^{\#}$	-4.563***$^{\#+}$	-3.632**(1)	0.245***(10)
	K	-3.394*$^{\#}$	-7.380***$^{\#+}$	-3.945***(1)	0.101(4)
	E	-3.986**$^{\#+}$	-7.247***$^{\#+}$	-1.107(4)	0.127*(4)
	C	-3.116$^{\#}$	-7.348***$^{\#+}$	-3.491**(1)	0. 062(3)
	P	-1.846	-4.386***$^{\#+}$	-2.755(1)	0.120*(3)
Second Differences					
Intercept only	Y				~~0.073(3)~~
	E			-9.274***(3)	~~0.145(4)~~
	P	-3.343**$^{\#}$		-5.965***(1)	0.079(4)
Intercept and trend	Y				0.065(3)
	E			-7.572***(3)	0.115(4)
	P	-3.345*$^{\#}$		-6.265***(1)	0.080(3)

Note: The statistics are respective test statistics. *, ** and *** indicate 10, five and once percent level of significance respectively. The null hypotheses of unit roots are tested against the alternatives of stationarity except for Kpss as the nulls are stationarity hypotheses tested against the alternatives of unit roots. Number of lag selected in dfuller and pperron are three, but higher and lower lags are also examined. The superscripts of # represents the statistical significance at lower lag orders and + shows the significance at higher lags. Dfgls and Kpss select the number of maximum lags according the method proposed by Schwert (1989) but the optimal lags are selected based on minimum Schwarz information criterion and Newey and West (1994), respectively, as shown in parentheses.

Table 2 Unit root test with structural break

Zandrews		Levels	Zandrews		First differences
Intercept only	Y	-2.769(1985)	Intercept only	Y	-5.371**(1985)
	K	-4.493(2002)		K	-7.103***(2001)
	E	-1.933(1986)		E	-8.910***(1986)
	C	-5.397**(2001)		C	-7.373***(1993)
	P	-1.271(2000)		P	-6.307***(2000)
Intercept and trend	Y	-2.746(1985)	Intercept and trend	Y	-6.357***(1988)
	K	-5.892***(1999)		K	-7.111***(2001)
	E	-2.767(2003)		E	-8.034***(1986)
	C	-5.219**(2001)		C	-7.658***(2001)
	P	-4.134(1998)		P	-6.078***(2000)

Note: Zandrews is based on Andrews and Zivot (1992). The test allows for endogenously determined single structural change. The numbers in the parentheses are years of structural change.

4. Results and discussion

Perron (1989) argues that with allowing a structural break in the level or the slope of the trend function, the unit root is highly rejected if the fluctuations are stationary around a breaking trend function where a standard unit root test fails to reject the unit root. However, Perron's method that modified augmented Dickey-Fuller (Dfuller) was criticized since exogenously determining the break invalidates the distribution theory of Dfuller itself (Christiano 1992). Due to the critic, Glynn et al. (2007) shows that there were some studies focused on the endogenously determined structural break of time for instance a study by Zivot and Andrews (1992) (Zandrews) which is used in this study. On this regard, Glynn et al. also argue that the unit root tests that allows for the possible presence of the structural break has at least two advantages; (i) the test prevents bias towards non-rejection of the unit root and contemporaneously, (ii) provides further related information regarding any significant policy, regime and other changes that associated with the break. As comparison, we also provide Dfuller, Pperron, dfgls and Kpss tests results. Table 1 and Table 2 display both types of unit root tests. As beenargued, Table 1 shows that traditional unit root tests tend to reject stationarity conditions. Therefore, the table shows the maximal lag order is two for *Y*, *E* and *P*. After considering the structural breaks which are endogenously determined, all variable are at least stationary at order one, *I*(1). In addition, *K* and *C* are stationary at levels, *I*(0). The selected breaks are shown in parentheses.

Even though the integration order is one and zero, only the maximal order matters. Hence, we select $d = 1$. Next, we determine optimal lag length (p) of VAR(p). Based on minimum values of FPE, AIC, HQIC and SBIC shown in Table 3, p can be either 1, 3 or 4. However, all stability, normality and autocorrelation of residuals tests suggest $p = 1$. The VAR(1) satisfies stability condition such that all the eigenvalues lie inside the unit circle. If VAR is stable, then it is invertible. The IRF and variance-decompositions are also interpretively known. Jarque-Bera test of normality also indicates the VAR is in overall normal. LM test also fails to reject null hypothesis of no autocorrelation.

Table 3 Optimal lag length selection criteria for VAR(*p*)

Lag	FPE	AIC	HQIC	SBIC
0	2.7e-10	-7.851	-7.776	-7.596
1	6.7e-14	-16.202	-15.811	-14.730*
2	7.6e-14	-16.387	-15.671	-13.687
3	5.1e-14	-17.801*	-16.759*	-13.874
4	-0.6e-45*	.	.	.

Once, *p* and *d* are known, we can augment a new VAR(1+1). To check for robustness, we test each equation in VAR(1+1) for robustness. Table 4 exhibits the tests results of chi-squares except for Ramsey RESET test where F statistic is used. The high values of adjusted R^2 indicate that all equations are highly explained except for capital equation. Cameron-Trivedi's information matrix test shows all regression equations in VAR are overall not normally skewed, highly kurtosis or heteroskedastic, though the Breusch-Pagan test rejects homoscedasticity for capital equation but not for the rest. The Ramsey RESET of omitted variables finds evidence of omitted variable for *Y* and *E* equations. This finding is expected as *Y* and *E* may be influenced by other factors not included in the VAR. However, high value of adjusted R^2 has assured that these two equations are well-explained. In addition, the errors for all equation are not serially correlated at high order. Durbin's test also indicates the same. The ARCH effects are also absent in residuals of all equation. Once, we have satisfied with the diagnostic tests we proceed to Granger non-causality test.

Table 4 Diagnostic tests of VAR(1+1)

Equation	Adj. R^2	Ramsey RESET	Breusch-Pagan	Cameron-Trivedi	ARCH LM	Breusch-Godfrey	Durbin
Y	0.994	3.710**	2.090	33.410	0.040	1.695	0.976
K	0.509	0.750	5.620**	35.760	0.162	1.694	0.976
E	0.975	3.020*	0.750	34.560	0.175	0.369	0.202
C	0.947	0.500	0.780	39.820	0.730	0.142	0.077
P	0.999	2.080	0.010	42.050	0.103	0.344	0.188

Note: ***, ** and * indicate one, five and 10 percent of significance levels.

The causality test is imposed on first part of lag of VAR(1+1). The T-Y method differs from traditional Johansen's test as the latter test for all lags exclusion. Nonetheless, both methods used Wald test of statistic to measure causal relationship. Table 5 reports Wald statistics of causality. The results show no bidirectional relationship between output, capital, energy use, emissions and labour. This finding overrules feedback effect between output, energy use and emissions in Bahrain. The results also show that emissions are strictly endogenous as it does not affect any of remaining variables. In contrast, output seems to be strictly exogenous. However, there are unidirectional causal relationships from output to capital, energy use and emission, from capital to energy use and emissions, from energy use to emissions, and lastly from labour to emissions. This finding rules out that output growth is dependent on labour and capital but instead, output affects capital accumulation. This relationship implicitly explains the dependence of Bahrain's national economy on oil income. This oil income has contributed significantly to an increase in capital accumulation where the capital is used for development of other economic sectors but the contributions of these sectors are far from enough to affect growth later or give feedback effect. Still, the increase in capital accumulation (initially influenced by output) affects energy use where the latter finally causes emissions. Besides that, labour also affects emissions positively. This finding contradicts previous studies for example by Sotyas et al. (2007), Sotyas and Sari (2009) and Zhang and Cheng (2009). All of them conclude that emissions can be reduced through reduction in energy use since both two variables do not have causal relationship with output. However, our result is consistent with Al-Iriani (2006) and Mehrara (2007). They find that there is unidirectional causality running from output to energy use.

Table 5 Granger non-causality test results

	Independent variables				
Dependent variables	Y	K	E	C	P
Y	.	1.867	0.649	4.503	1.606
K	7.075**	.	2.614	0.126	4.290
E	15.926***	5.648*	.	1.167	0.004
C	8.923**	20.851***	12.526**	.	14.520***
P	0.796	1.690	2.896	0.298	.

Note: ***, ** and * indicate one, five and 10 percent of significance levels.

4.1 IRF

Impulse response functions (IRF) shows that output and labour are not influenced by other variables except themselves. This is consistent with Granger test result. On the hand, a shock in output has positive and permanent influence on capital and energy use. However, an output shock has initial negative effect on emissions before it dies out after third period. Though, the impact of innovation in output initially reduce emissions, but its impact through shocks in capital increases emissions after the second period. In addition, output shock and capital shock also affect energy use to increase permanently. Therefore, a shock in energy use has initial positive effect on emission, but in later periods the effect fades out. Not surprisingly, labour shock also positively affect emissions. These IRF as shown in Figure 3 are consistent with Granger test results in Table 5. The impact of output shocks on capital, energy use and emissions implies how dependence is future growth of Bahrain on current GDP. Since, oil income contributes mainly to GDP, it indicates how closely the economic growth with energy use which further proves that energy cut is not the best solution of emission reductions.

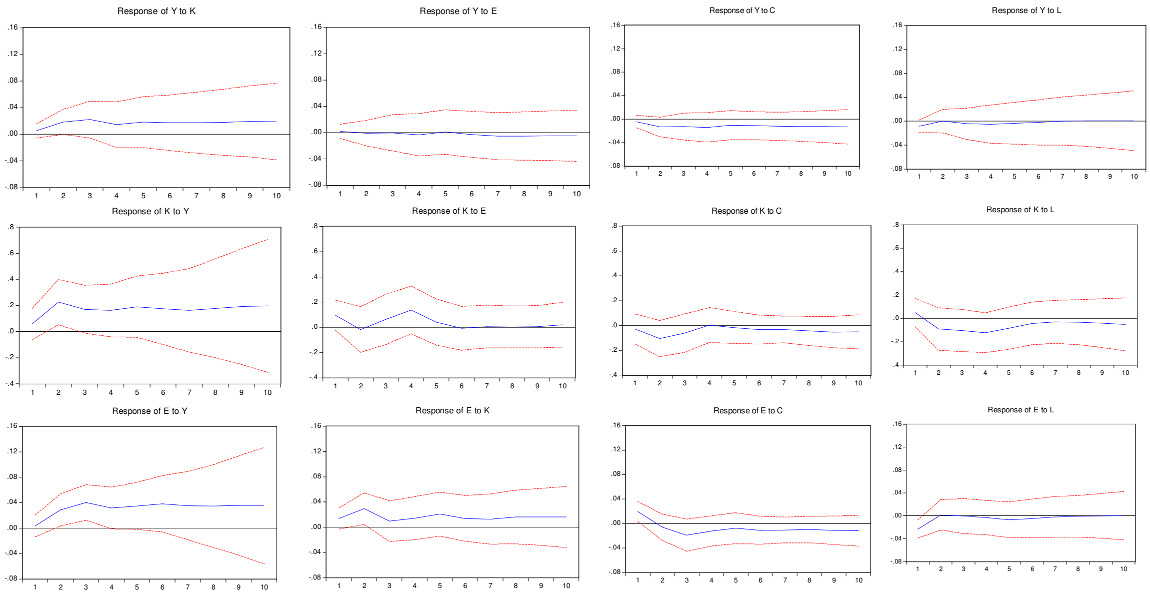
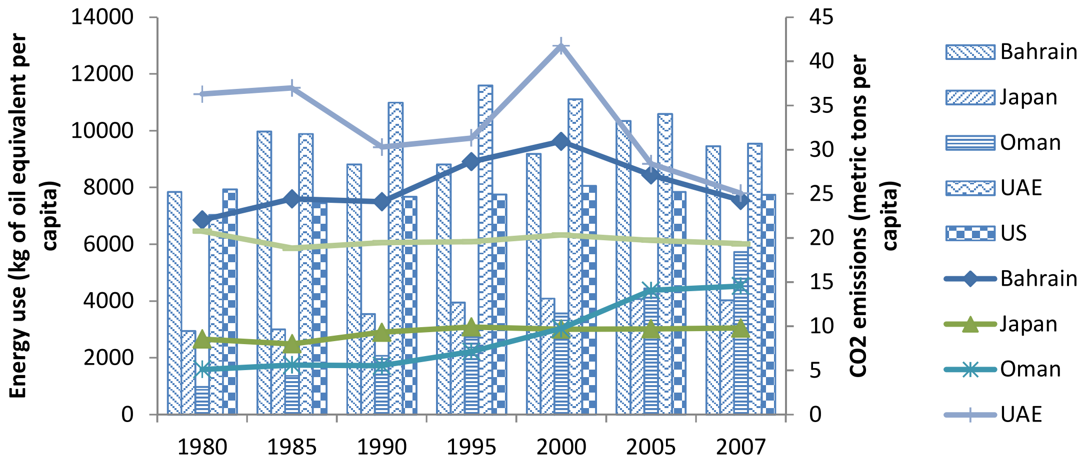


Figure 3 IRF: Response to generalized one standard deviation innovations

5. Policy implications

Currently, per capita energy consumption of oil equivalent by Bahrainis is relatively large. The amount is even larger than amounts consumed in the United States (US) and Japan. In 1980, a Bahrani consumed 7847kg of oil equivalent of energy. In 2007, the amount increased to 9456kg which higher than Japan and US as their per capita uses are only at amounts of 4033kg and 7747kg, respectively. Figure 4 shows per capita energy consumption in Bahrain as compared to neighbours and some developed countries. This huge consumption has contributed to high per capita emissions. In 2007, Bahrain used one third of energy she produced domestically. Most of domestic uses came from industrial and electricity generating sectors. Both sectors used natural gas as main fuels. Burning natural gases will produce GHG as both sectors have no alternative energy resources. This evidence supports how dependence is Bahrain on fossil fuel to generate her economy. Therefore, simply cutting the emissions will hurt the whole economy. Therefore, finding new sources of energy can be considered. In this case, Alnaser (1995) has studied the possibility of finding new renewable energy resources. Alnaser estimated energy productions of solar power, wind power, tidal power, wave power and water current power. However, Alnaser finds these sources of energy were very costly in term of maintenance and storage. Abulfotuh (2007) agrees that initial investment to install greener technologies and implement renewable energy sources is high. However, Alnaser's study did not rule out any long run economic benefits from the sources. The greener sources of energy can only be implemented if future benefits from energy saving outweight the costs of saving (Abulfotuh 2007). Doukas et al. (2006), on the other hand, argue that GCC has existing potential to develop renewable energy sources especially solar energy. This new energy will benefit rural areas as there many rural areas in GCC. Therefore, Doukas et al. suggest the use of basic small scale but cheap solar energy for houses, telecom towers, heaters, commercial buildings and rural communities.



Source: World Bank (2011), World Development Indicators

Figure 4 Per capita energy use and CO2 emissions

Furthermore, to reduce energy use Akbaba (1999) suggests the use of energy efficient motors used by industry as standard operating motors used three quarters of electricity in Bahrain. Akbaba finds energy efficient motors is nearly five percent more efficient than standard motors. This means that it can reduce fuel burning which in turn cut the emissions. Besides, to avoid emissions released into the air, Al-Qahtani (1996) recommends the use of carbon dioxide emitted by industry to replace natural gas used in oil extraction industry where it is used to maintain production rate. The carbon dioxide is obtained from other industries such as electric generating plants. However, the cost to retrieve the carbon dioxide is quite expensive. To reduce energy use by commercial buildings, Radhi (2009) recommends the use of envelope thermal insulation codes is not enough as it failed by a simulation study to achieve 40 percent reduction in electricity reduction targeted by the Electricity and Water Authority.

Finally, we can conclude that Bahrain need to consider carefully the energy use reduction in order to reduce emissions as required by the Kyoto Protocol as she already ratified it in 2006. A simply reduction in emissions may cause output shrinking and capital loses. Though, installing new greener capitals and retrieving emissions into byproducts may initially cost a lot of funds, long run effects of these energy conversation measures may benefit Bahrain more in term of sustainable energy sources and long-run oil reserve to ascertain more consistent income for future generations. Mutual cooperation with other oil producing countries may be helpful. The step taken by NOGA in collaboration with Masdar of Abu Dhabi, UAE to implement environmentally projects is supported and mutually beneficial without hurting the economy and this step to reduce emissions does not only benefit Bahrain but other neighbouring GCC countries. More importantly, the step should be taken gradually but consistently.

6. Conclusion

GHG emissions and climate change have attracted concerns of world leaders to find solutions to avoid global warming. Kyoto Protocol was then adopted in the late of 1997. Bahrain ratified Kyoto Protocol in 2006. The Protocol requires Bahrain to reduce GHG emissions to certain quantified limitation by taking appropriate measures for example enhancing energy efficiency, practicing sustainable development, formulating green policies and so on. Most emissions in Bahrain are associated with its dependency on oil industry and other fuel related industries. Therefore, this study is aimed to examine the causal relationship between economic growth, energy consumption and emissions in Bahrain. To identify the relationship, we employ Toda and Yamamoto's (1995) approach. This approach has two advantages as it does not require the data to be at the same order of integration and it also suits small but typical and finite sample size of data. In addition, the finding from this investigation is crucial as it may recommend steps that should be taken by Bahrain to reduce emissions without affecting her national output. This study finds that there are unidirectional relationship between output, capital, energy use, labour and emissions. It also finds that there is causality running from output to capital, energy use and emissions, but not vice versa. Based on these results, this study suggests emissions cut cannot be simply taken without sacrificing the economy. Nonetheless, other measures are recommended as discussed above, where Bahrain may gradually replace existing capitals with more energy efficient capitals. Bahrain also can find new energy resources. Adopting new energy policy with green energy resources may hurt current energy industry, but implementing small scale energy resources may be more viable and cost-effective.

References

Abulfotuh, F. (2007). "Energy efficiency and renewable technologies: The way to sustainable energy future." Desalination **209**: 275-282.

Akbaba, M. (1999). "Energy reservation by using energy efficient electric motors." Applied Energy **64**: 149-158.

Alexander, R. (1994). "The investment-output ratio in growth regressions." Applied Economics Letters **1**(74-76): 74.

Al-Iriani, M. (2006). "Energy-GDP relationship revisited: An example from GCC countries using panel causality." Energy Policy **34**: 3342-3350.

Alnaser, W. (1995). "Renewable energy resources in the State of Bahrain." Applied Energy **50**: 23-30.

Al-Qahtani, H. (1996). "Retrievable carbon dioxide in the State of Bahrain." Applied Energy **54**: 1-9.

Andrews, D., Zivot, E. (1992). "Further evidence on the Great Crash, the oil price shock, and the unit-root hypothesis." Journal of Business and Economic Statistics **10**: 251-270.

Ang, J. (2008). "Economic development, pollutant emissions and energy consumption in Malaysia." Journal of Policy Modeling **30**: 271-278.

Aslanidis, N. (2009) Environmental Kuznets curves for carbon emissions: A critical survey. Fondazione Eni Enrico Mattei Working Papers 1-33

Authority, N. O. a. G. (2010). "Strategic Objective." Retrieved 9 February 2012, 2012, from http://www.noga.gov.bh/WebsiteV2.0/en/getinfo.asp?cid=850&menu=30&section=30#.

Bank, W. (2011). World Development Indicators, ESDS International, University of Manchester. **September 2011**.

Baxter, E. (2009, 22 February 2012). "Masdar to help Bahrain cut its carbon footprint." Arabianbusiness.com. Retrieved 22 February 2012, 2012, from http://www.arabianbusiness.com/masdar-help-bahrain-cut-its-carbon-footprint-16860.html.

Bo, S. (2011). "A literature survey on environmental Kuznets curve." Energy Procedia **5**: 1322-1325.

Board, B. E. D. (2008). "Bahrain Economic Quarterly." Retrieved 9 February 2012, 2012, from http://www.bahrainedb.com/quarterly-review.aspx.

Chontanawat, J., Hunt, L., Pierse, R. (2008). "Does energy consumption cause economic growth?: Evidence from a systematic study of over 100 countries." Journal of Policy Modeling **30**: 209-220.

Christiano, L. (1992). "Searching for a break in GNP." Journal of Business and Economic Statistics **10**: 237-250.

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

Doukas, H., Patlitzianas, K., Kagiannas, A., Psarras, J. (2006). "Renewable energy sources and rationale use of energy development in the countries of GCC: Myth or reality?" Renewable Energy **31**: 755-770.

Friedl, B., Getzner, M. (2003). "Determinants of CO2 emissions in a small open economy." Ecological Economics **45**: 133-148.

Fund, I. M. (2011). World Economic Outlook, ESDS International, University of Manchester. **September 2011**.

Glynn, J., Perera, N., Verma, R. (2007) Unit root tests and structural breaks: A survey with applications. Revista De Metodos Cuantitativos Para La Economia Y La Empresa **3**, 63-79

Hamit-Haggar, M. (2012). "Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective." Energy Economics **34**: 358-364.

Johansen, S. (1988). "Statistical analysis of cointegration vectors." Journal of Economic Dynamics and Control **12**: 231-254.

Johansen, S. (1991). "Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models." Econometrica **59**: 1551-1580.

Kijima, M., Nishide, K., Ohyama, A. (2010). "Economic models for the environmental Kuznets curve: A survey." Journal of Economic Dynamics and Control **34**: 1187-1201.

Lutkepohl, H. (1982). "Non-causality due to omitted variables." Journal of Econometrics **19**: 367-378.

Mehrara, M. (2007). "Energy consumption and economic growth: The case of oil exporting countries." Energy Policy **35**: 2939-2945.

Newey, W., West, K. (1994). "Automatic lag selection in covariance matrix estimation." Review of Economic Studies **61**: 631-653.

Ozturk, I. (2010). "A literature survey on energy-growth nexus." Energy Policy **38**: 340-349.

Payne, J. (2010). "Survey of the international evidence on the causal relationship between energy consumption and growth." Journal of Economic Studies **37**: 53-95.

Perron, P. (1989). "The Great Crash, the oil price shock, and the unit root hypothesis." Econometrica **57**: 1361-1401.

Phillips, P. (1995). "Fully modified least squares and vector autoregressive." Econometrica **63**: 1023-1078.

Radhi, H. (2009). "Can envelope codes reduce electricity and CO2 emissions in different types of buildings in the hot climate of Bahrain?" Energy **34**: 205-215.

Schwert, G. (1989). "Tests for unit roots: A Monte Carlo investigation." Journal of Business and Economic Statistics **7**: 147-159.

Song, T., Zheng, T, Tong, L. (2008). "An empirical test of the environmental Kuznets curve in China: A panel cointegration approach." China Economic Review **19**: 381-392.

Sotyas, U., Sari, R. (2009). "Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member." Ecological Economics **68**: 1667-1675.

Sotyas, U., Sari, R., Ewing, B. (2007). "Energy consumption, income, and carbon emissions in the United States." Ecological Economics **62**: 482-489.

Stern, D. (2004). "The rise and fall of the environmental Kuznets curve." World Development **32**: 1419-1439.

Toda, H., Yamamoto, T. (1995). "Statistical inference in vector autoregressions with possibly integrated processes." Journal of Econometrics **66**: 225-250.

UNFCCC (1998). Kyoto Protocol to the United Nations Framework Convention on Climate Change. Kyoto Protocol to the United Nations Framework Convention on Climate Change. UNFCCC, UNFCCC**:** 1-21.

Yamada, H., Toda, H. (1998). "Inference in possibly integrated vector autoregressive models: Some finite sample evidence." Journal of Econometrics **86**: 55-95.

Zhang, X., Cheng X. (2009). "Energy consumption, carbon emissions, and economic growth in China." Ecological Economics **68**: 2706-2712.