Energy use, emissions, economic growth and trade: A Granger non-causality evidence for Malaysia

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Energy use, emissions, economic growth and trade: A Granger non-causality evidence for Malaysia

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Abstract

This paper investigates the relationship among energy, emissions and economic growth in Malaysia with the presence of trade activities. We employ Johansen's (1995) approach to investigate the relationship. Using annual data from 1971 to 2007, the empirical results shows that there are long-run causalities among energy, emission and economic growth, and among energy, emissions, export and capital, while the short-run Granger non-causality test shows that there are unidirectional causalities running from energy to economic growth and capital, from economic growth to capital and from emissions to export. The short-run results show that the Malaysian data support the growth hypothesis relationship between energy and economic growth, in which the conservation policies such as reduction measures in energy use will not work to improve the environment. In contrast, in the long-run, the feedback hypothesis is observed. Therefore, we suggest the policy makers in Malaysia to focus on long-run conservation policies.

Keywords: Energy; Emissions; Economic growth; Export; Malaysia; VECM; Causality; Impulse-response function

JEL classification: C32; Q43; Q50

1. Introduction

Kyoto Protocol requires signatory parties to committedly reduce greenhouse gases (GHGs). The Protocol document outlines action plans to achieve the reduction objective. The protocol recommends sustainable development and promotes energy efficiency. Malaysia has participated in the Climate Change Convention since 1993, but signed the Protocol in 1999. Insofar as Malaysia has given full commitments to implement GHG reduction measures, two reports have been submitted to United Nations Framework Convention on Climate Change (UNFCCC), an international conference that gathers all signatory parties and observers of the Kyoto Protocol. The protocol also outlines six types of GHGs, namely are carbon dioxide

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(CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). These GHGs are closely related combustion activities such as electricity generating, manufacturing activities, transportation by industries, and final consumption by households. Since there is a close relationship between emissions and economic activities, any GHG reduction measures should be taken properly so that the measures cause no negative impacts on the economy.

Therefore, this paper is aimed to investigate the relationship among energy, emissions and economic growth in Malaysia. This relationship is examined with taking into account the trade openness because Malaysia is a very open economy. Both short-run and long-run causal relationships are considered to find out causes and effects of any possible reduction measures on economic activities. The empirical finding of this study can enlighten the policy makers possible appropriate measures should be taken with consideration that Malaysia is a developing and open economy that relies on energy intensive industries to produce goods for exports. This paper utilizes annual data from 1971 to 2007. The results indicate short-run unidirectional causalities running from energy to economic growth and capital, from economic growth to capital, and from emissions to export. The results also show long-run causalities among energy, emission and economic growth, and among energy, emissions, export and capital. These results rule out conservation policies in the short-run, while in the long-run the policies are implementable.

The remaining sections of this paper are as follows: The next section will discuss previous studies. The production function and its econometric model of vector-error correction model (VECM) are discussed in Section 3. Next, we discuss empirical results. Last, we conclude with some recommendations and policy implication.

2. Literature reviews

The issue of energy and economic growth has attracted many economists to study. They employed various econometric approaches to understand the issue. There are three events that have prompted economists to study the issue. The events are; first, the oil shock happened in 1970s; second, the adoption of the Kyoto Protocol in late 1997; and third, the recent increase in energy prices due to skyrocketing increases in crude oil prices. The studies have been extensively reviewed by Payne (2010) and Ozturk (2010). Both of them show that majority of the studies focused on causal relationship between energy use and economic growth. However, they find that the studies find no conclusive finding regarding the relationship. Payne argues that there are many reasons have caused the failure which are, inter alia, heterogeneity in climate conditions, varying energy consumption patterns, different stages of economic development, different econometric approaches and different time horizons of dataset. Ozturk (2010), also argues that the diverse relationship was due to different methodologies and datasets used that embed with different specific characteristics.

Payne (2010) also highlights that some previous studies, for examples Chiou-Wei et al. (2008), Jinke et al. (2008), Narayan and Prasad (2008), and Reynolds and Kolodziej (2008) employ bivariate approach that is subjected to a severe weakness, as it may suffer omitted variable bias problem. TO avoid this problem, other studies, for examples Huang et al. (2008), Lee and Chang (2008), Lee at al. (2008), Payne and Taylor (2010), Sari et al. (2008), Sotyas and Sari (2009), Yuan et al. (2008), and Payne (2009) has included other factors such as labour and capital in the regression model. However, Payne (2010) also points out that many studies focus only on directions of causality, but they are lacks of empirical result interpretation in term of the statistical signs and their magnitudes of coefficients. These lacks may cause lacking policy recommendation.

To understand the interpretation of statistical signs and causal directions, Payne (2010) and Ozturk (2010) have summarized three types of energy-economic growth relationship based on previous studies. They are,

(i) unidirectional causality either the causality is running from energy to economic growth which is called growth hypothesis or from economic growth to energy (conservation hypothesis),
(ii) bi-directional causality between energy and economic growth or called feedback hypothesis, and
(iii) no-causal relationship between energy and economic growth (neutral hypothesis).

For the growth and reservation hypotheses the signs can be either positive or negative, while the feedback hypothesis has only a positive sign. For growth hypothesis, if the sign is positive, it means that the increases in energy cause increases in economic growth. Therefore, any conservation policy to reduce energy use will cause reductions in economic growth. On the hand, if the sign is negative, this signifies that the increases in energy reduce economic growth. This happens due to capacity constraints of the economy, inefficiency in energy supply, excessive use in energy by unproductive sectors or structural economic moving to less energy intensive sectors.

For conservation hypothesis, the positive sign implies that the increases in economic growth will result in increases in energy use. If the relationship holds, any conservation policy that is carried out will not adversely affect the economy, whereas if the sign is negative, the relationship, otherwise, represents political, infrastructural, or management constraints of resources, that generate energy inefficiencies and demand reduction in energy consumption. For the feedback hypothesis, the positive sign indicate the interdependence of energy and economy growth such that an increase in energy (economic growth) causes increases in economic growth (energy) in both ways. Under this feedback hypothesis, conservation policies are most welcomed as the policies do not only adversely affect the economy but also increase the economy further, instead.

Since bivariate models suffer omitted variable bias problem, we then prefer multivariate model approach where we can examine both energy-economic growth and environment-economic growth relationships in a model. There are two types of this multivariate approach used by in previous studies. First, they adopt environmental Kuznets curve (EKC) hypothesis. Second, they employ multivariate vector autoregressive (VAR) model. The EKC approach argues that the environment and economic growth has a non-linear relationship with an inverted U-shaped curve. In the early stages of economic development, environmental degradation is 'necessary' for economic growth. Once the economy achieves a threshold of economic development, environment cleanliness plays an important role in the economy. Environmental degradation affects the economy adversely, instead. Stern (2004), Dinda (2004), Aslanidis (2009) and Kijima et al. (2010) provide useful reviews of the EKC studies.

However, Stern (2004) finds out that previous EKC studies fail to provide robust finding on the inverted U-shaped relationship between environment and economic growth, as income increases. Similarly, Dinda (2004) also argues that previous EKC studies are not able to provide concrete finding when the negative correlation between environmental degradation and economic growth starts. Based on this argument, Dinda suggests a searching for new economic models that are able to reflect important feedback effects between economic growth and environment. A survey by Kijima et al. (2010) also shows the similar conclusion regarding the 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 modelling.

In contrast, a multivariate VAR model approach is able to avoid omitted-variable bias problem because the VAR model can be augmented to both insert environment and production factors. Also, it differs from the previous bivariate energy-economic growth studies as the environmental effects can be interpreted explicitly in the model. Besides, the VAR model also allows for endogenous characteristics of variables, for example, output variable is treated as an endogenous variable where the variable is treated as exogenous in the EKC model. On the basis of these arguments, we utilize the multivariate VAR model to study the environment-economic growth in the presence of trade variable to examine for trade openness. Sotyas et al. (2007), Sotyas and Sari (2009) and Zhang and Cheng (2009) use also this approach. Sotyas et al. (2007) examine energy, economic growth and carbon emission in the United States (US). Their study finds that that income does not Granger cause carbon emission in the long run. Similar finding is also found by Zhang and Cheng (2009) in China and Sotyas and Sari (2009) in Turkey. This finding indicates that environmental conservation can be implemented without hurting economic growth.

With respect to the Malaysian case, majority of studies employ bivariate VAR approach. Among of them, the earliest study on Malaysia is done by Masih and Masih (1996). Their study finds that no short-run and long-run energy-economic growth relationship in Malaysia using a sample of data from 1955 to 1990. Chen et al. (2007) also use bivariate model to study energy (electricity) use and economic growth. Using the annual data from 1971 to 2001, they find that there is no cointegration between electricity and economic growth, but there is short-run causality running from economic growth to energy use. Also, Chontanawat et al. (2008) compare developed and developing countries results using a bivariate model. For Malaysian case, they find no cointegration and causality between energy use and economic growth.

However, with the similar bivariate approach, Yoo (2006) finds there is short-run bidirectional causality between energy (electricity) and economic growth for a period from

1971 to 2002. Similar finding is found by Chiou-Wei et al. (2008) using annual data from 1971 to 2003. This finding suggests the implementation of conservation policies can be carried out in Malaysia without harming the economy.

Next, using the multivariate VAR approach, Mahadevan and Asafu-Adjaye (2007) compare between energy importing and exporting countries. For Malaysian case, they find that there is bidirectional causality between energy and economic growth in Malaysia in both short- and long-run results. The data used ranges from 1971 to 2002. In constrast, Ang (2008) adopts a VAR approach for EKC model. Ang (2008) uses annual data for a period from 1971 to 1999. He finds that pollution and energy use are positively related with economic growth in the long run. Ang (2008) also finds that there are short-run and long-run causality running from economic growth to energy consumption. However, the feedback effects happen only in the long-run between energy and economic growth. There is also long-run causality from emission to economic growth in the long-run. However, Ang (2008) finds contradictory results between short-run and long-run relationship regarding conservation policies that can be implemented in Malaysia. Based on feedback effects, it can be concluded that the conservation policies are most welcome. Instead, based on weak exogeneity test of pollutant-economic growth link, Ang (2008) argues the reversed.

Overall, previous studies provide inconclusive finding regarding the energy and economic growth in Malaysia. Furthermore, current study by Ang (2008) employs controversial EKC approach as has been discussed above. Out of these studies, only Ang (2008) incorporates pollutant indicator to examine further the link between energy and economic growth as energy use is usually associated with GHG emissions. However, since Ang (2008) employs short time series data for a VAR model may invite econometric problem as discussed in Yamada and Toda (1998). To avoid the problem, we expand the data period and employ a multivariate approach to include factors of production.

3. Econometric methodology

3.1 Model

To derive an estimated model, a production function is presented as a function of capital stock and labour, as follows,

$$Y = F(K, L) \tag{1}$$

Previous studies include energy, E, as the third factor of production, thus Equation (1) is augmented to be,

$$Y = F(K, E, L) \tag{2}$$

Let the production function is a Cobb-Douglas-type production function. Equation (2) can be transformed into,

$$Y = K^a E^b L^c \tag{3}$$

where $a + b + c \leq 1$ to represent constant elasticity of substitution, in which the economy cannot expand beyond its carrying capacity measured in inputs availability. Taking logarithms for Equation (3) and scaling it with labour to produce per labour variables. This gives,

$$LYP = c + a * LKP + b * LEP + d * LCP + e * LXP \quad (4)$$

In Equation (4), LCP which is per capita greenhouse gas (GHG) emissions, is plugged into the model to measure the environmental effects of the economy. Next, to measure distinctive effects of trade on economic growth, an openness indicator is also considered because Malaysia is a very open economy, where its export exceeds its own output. It also argued that trade orientation policy may cause environmental degradation in which a developing country may intensively use its labour and natural resources in goods production. To measure the trade effect, we use a proxy of export variable scaled by labour, LXP, to be inserted in the model.

3.2 Data sources

Output, capital, energy use, emissions and export are annual data taken from the World Development Indicators (WDI) (2011) for a period from 1971 to 2007. Output is measured by the gross domestic product (GDP). Capital is the gross fixed capital formation which excludes net changes in the level of inventories. Energy use is measured in kilos of oil equivalent. Emissions are proxied by CO2 emissions measured by metric tons. Though there are six types of GHG emissions, CO2 is used as the data is available annually. Besides, CO2 also constitutes major part of emissions. Previous researchers such as Sotyas et al. (2007), Ang (2008), Sotyas and Sari (2009), Zhang and Cheng (2009), and Hamit-Haggar (2012), to name a few, use CO2 as an emission indicator. Export is the total export of goods and services.

Output, capital and export are expressed in real term of local currency (Malaysian Ringgit). All these five variables are scaled by population, as the proxy of labour, to obtain per capita data. Ang (2008), Halicioglu (2009) and Lean and Smyth (2010) used per capita data in their models. Population has been used as a proxy of labour in Song et al. (2008). Population data is also taken from the WDI.

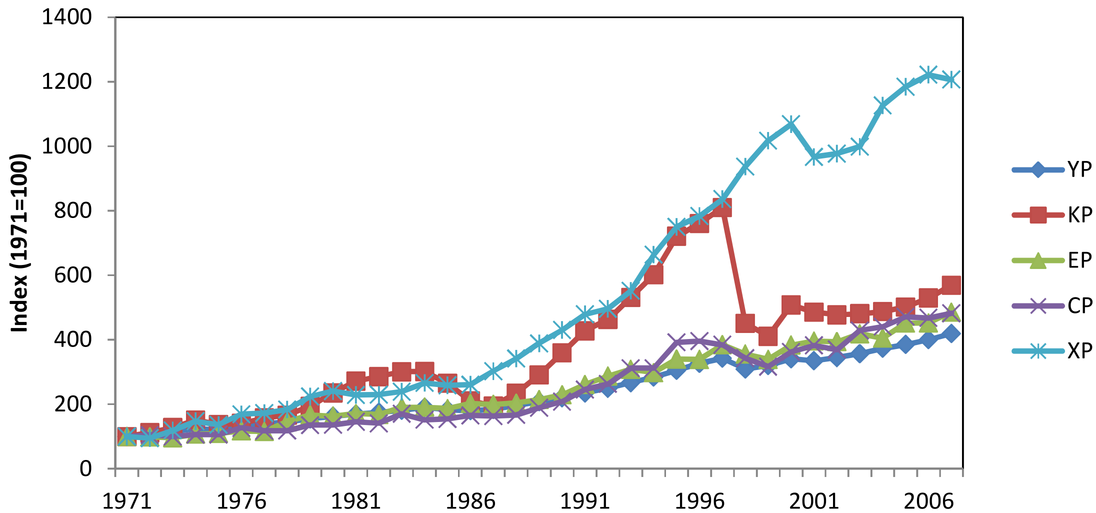

Figure 1 Variable trends in index forms (1971=100) before taking logarithms

Using 1971 as the base year, an index can be constructed for each variable. Figure 1 shows the plots of the indices. It is shown that there are trend and co-movement in the variables. The co-movement suggests a long-run relationship in the variables. On the hand, Figure 2 represents plots of variable series in logarithms. The series also show trending pattern.

3.3 Vector-error correction model (VECM)

To examine directions of causal relationship between variables, a method by Johansen (1995) is employed. This method suits the model in Equation (4) as it analyses the stationary relationships between multiple series of variables. Johansen's method requires series to be integrated in the same order and non-stationary in levels. To determine the order, unit root tests are implemented. The tests include the augmented Dickey-Fuller (ADF) test, Phillips-Perron (PP) test, modified Dickey-Fuller of Elliott et al. (1996) (DF-GLS) test, Kwiatkowski et al. (1992) (KPSS) test and Zivot and Andrews (1992) (Zivot-Andrews) test. The first three tests are tested against the alternative hypotheses of stationarity. On the other hand, KPSS is tested against the alternative hypothesis of unit roots. However, ADF, PP, DF-GLS and KPSS do not take into account any structural break. In case of structural breaks, Perron (1989) argues that allowing a structural break in the level or the slope of the trend function, the unit root hypothesis is rejected if the fluctuations are stationary around a breaking trend function, whereas a standard unit root test fails to reject the unit root. Glynn et al. (2007) 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) the test provides further related information regarding any significant policy, regime and other changes that associated with the break. Therefore, following Zhang and Cheng (2009), Zivot-Andrews test is used to test for stationarity.

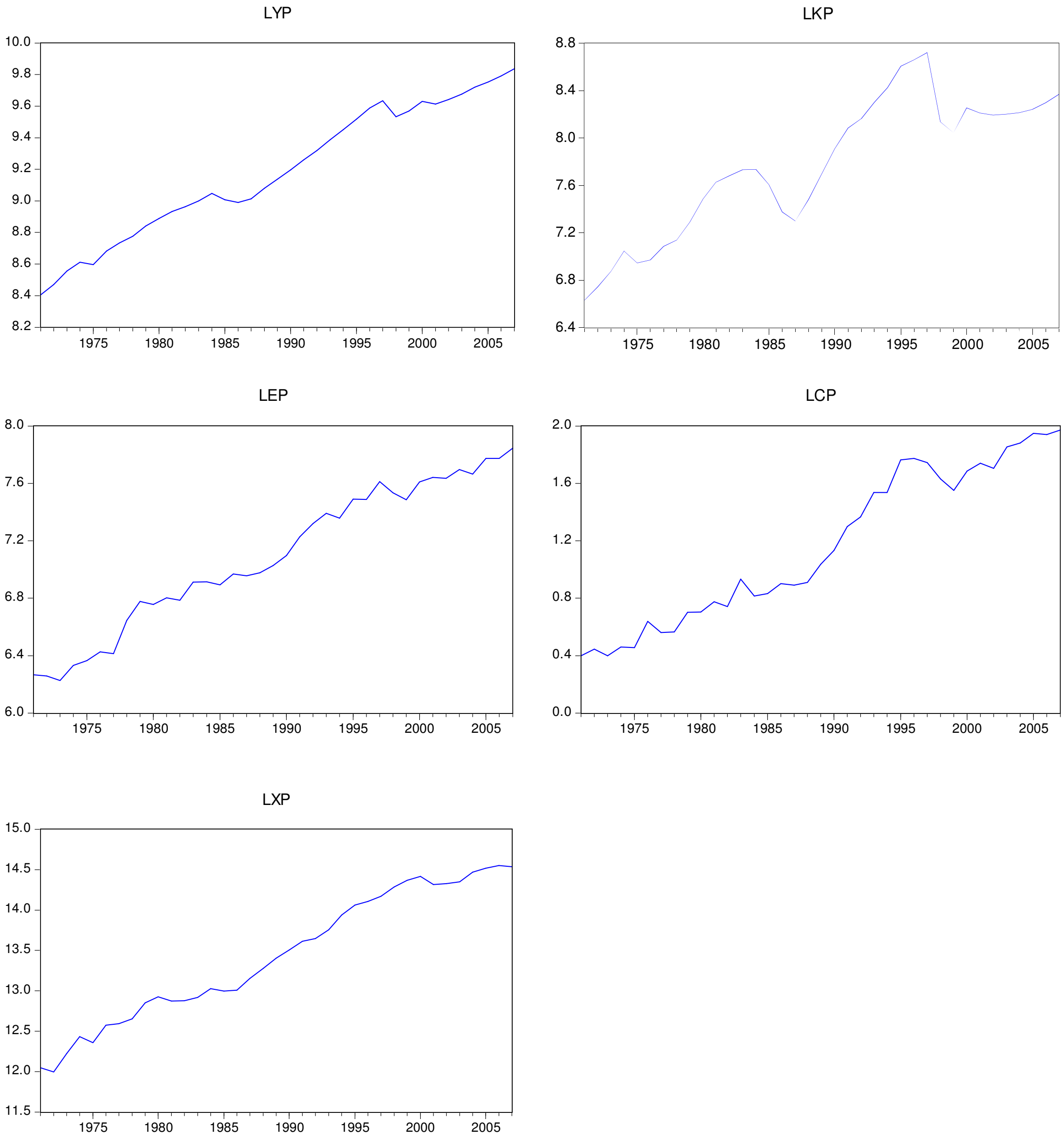

Figure 2 Plot of variables (in natural logarithms)

Before constructing a VECM, the optimal VAR lag order, p, should be determined. This information is crucial in determining the number of cointegrating equations in a VECM. The VECM will include one lag fewer than VAR. Hence, p must be greater than zero. Next, we determine the number of cointegration equation, or rank. Trace and maximum eigenvalue statistics are used to decide the number of ranks. If the variables are cointegrated, a VECM model can be constructed in a vector form of the first difference equation as follows,

$$\Delta y_t = \alpha\beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + v + \epsilon_i \quad (5)$$

where y_t is $K \times 1$ vector of endogenous variables, LYP, LKP, LEP, LCP, LXP, respectively; α and β are $K \times r$ matrix of parameters; Γ_i for all $i = 1,2, \ldots, p-1$ are $K \times K$ matrices of parameters; v is $K \times 1$ vector of parameters (intercepts) and $v = \alpha\mu + \gamma$; ϵ_i is $K \times 1$ vector of normally distributed errors. K is the number of variables included in the VAR system, while r is number of cointegrating equations. $\beta' y_{t-1}$ constitutes error correction term(s) (ECT). Alternatively, Equation (5) can also be presented as,

$$\Delta y_t = \alpha(\beta' y_{t-1} + \mu) + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \gamma + \epsilon_i \tag{6}$$

The ECT comprises of long-run causal relationship information. The coefficients of ECT in respective equations measure adjustment speed of the dependent variable to the long-run equilibrium. The second term of the right hand side comprises of short-run causal relationships. It describes short-run dynamics. Following Ang (2008), three Wald tests can be imposed, namely; Granger non-causality test to determine the significance of short-run causal relationship, weak exogeneity test for long-run causal relationship and lastly, overall exogeneity test for overall causal relationship. Finally, to diagnose the causality results, impulse-response function is estimated to verify long-run and short-run causalities with respect to responses of the variables to transitory and permanent shocks.

4. Empirical results

4.1 Unit root

Overall, the traditional unit root tests of ADF, PP and DF-GLS indicate that *LYP*, *LKP*, *LEP*, *LCP* and *LXP* are not stationary at level. However, the null hypothesis of stationarity in KPSS is failed to be rejected in levels for intercept and trend. According to Perron (1989), traditional unit root tests are biased towards non-rejection of unit root hypotheses if there is a structural break in the data. Therefore, it is suggested that the data to be split if the break is known. However, this technique causes losses in data's degree of freedom. This problem can be overcome using Zivot-Andrews test. This test allows for single structural break which is not exogenously predetermined, but endogenously determined by the data. Accordingly, the test also provides important break information that causes the variables to break away from a stationary trend. The breaks are presented in parentheses in Table 1. Last, we conclude that all variables are integrated of order one, $I(1)$. This criterion fulfils the main requirement of VECM that all variables should be not stationary at levels.

4.2 VECM

Before proceeding to VECM, optimal lag order for VAR(p) must be determined. To do that, several information criteria are used to determine the lag order where the results of the criteria are shown in Table 2. The table shows that all criteria indicate two lags except Schwarz information (SC) criterion which indicates one lag. To verify the optimal lag, three diagnostic tests, which are the VAR residual serial correlation LM test, the VAR residual normality test and the stability test are carried out. The results indicate that VAR(1) has serially correlated residuals at lag one, and reject null hypothesis of multivariate normal residuals for the case of skewness[3]. On the other hand, for VAR(2), all diagnostic tests are fulfilled in which the results indicate that the residuals are not serially correlated, and the residuals are multivariate normal for the case of skewness, kurtosis and Jarque-Bera tests. The VAR(2) also satisfy stability condition where all root lies inside the unit circle. This lag is also greater than zero. The stability condition is important because it determines whether it is invertible and its impulse-response functions can be derived.

Table 1 Unit root test results

	ADF	*PP*	*DF-GLS*	*KPSS*	*Zivot-Andrews* [a]
Intercept					
Level					
LYP	-1.325(0)	-1.293(2)	0.643(1)	0.728(5)**	-3.052(1998)
LKP	-1.675(1)	-1.749(0)	-0.675(1)	0.647(5)**	-4.320(1998)
LEP	-0.947(1)	-0.708(8)	0.818(0)	0.721(5)**	-4.288(1978)
LCP	-0.387(0)	-0.320(1)	0.615(0)	0.710(5)**	-4.284(1991)
LXP	-1.858(1)	-1.267(0)	0.082(1)	0.723(5)**	-2.720(2001)
First difference					
LYP	-4.965(0)***	-4.923(2)***	-4.748(0)***	0.143(2)	-5.652(1988)***
LKP	-4.170(0)***	-4.105(3)***	-4.136(0)***	0.180(0)	-4.716(1988)*
LEP	-7.278(0)***	-7.486(5)***	-6.798(0)***	0.108(7)	-7.492(1998)***
LCP	-7.132(0)***	-7.116(1)***	-7.239(0)***	0.078(1)	-8.619(1997)***
LXP	-6.013(0)***	-6.010(1)***	-4.510(0)***	0.163(1)	-7.740(1987)***
Intercept and trend					
Level					
LYP	-2.165(0)	-2.382(3)	-2.305(1)	0.078(4)	-3.126(1993)
LKP	-2.486(1)	-1.957(1)	-2.479(1)	0.119(4)	-3.886(1993)
LEP	-2.630(0)	-2.598(1)	-2.732(0)	0.117(4)	-4.194(1978)
LCP	-2.418(0)	-2.465(2)	-2.387(0)	0.083(4)	-4.107(1991)
LXP	-1.887(1)	-1.614(2)	-2.099(1)	0.083(4)	-3.274(1994)
First difference					
LYP	-4.970(0)***	-4.972(1)***	-5.097(0)***	0.061(2)	-6.019(1998)***
LKP	-4.176(0)**	-4.103(3)**	-4.305(0)***	0.048(1)	-5.159(1998)**
LEP	-7.242(0)***	-8.149(7)***	-7.100(0)***	0.099(8)	-8.614(1980)***
LCP	-7.028(0)***	-7.013(1)***	-7.239(0)***	0.076(1)	-8.659(1997)***
LXP	-6.312(0)***	-6.312(0)***	-5.709(0)***	0.072(0)	-7.875(1987)***

Note: ***, ** and * represent one, five and 10 percent levels of significance. Lag length for augmented Dickey-Fuller (ADF) and Elliott-Rothenberg-Stock DF-GLS tests, as in parentheses, is chosen based on Schwarz information criterion (SIC). Bandwidth (as in parentheses) for Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin tests (KPSS) is based on Newey-West method and its spectral estimation method is based on Bartlett kernel.
[a]Zivot-Andrews unit root test is based on Zivot and Andrews (1992) which allows for endogenously determined single structural breaks. The breaks are shown in parentheses.

[3] The results are not reported but available upon request from authors.

Next, before testing for cointegration rank, trend specification should be determined. Using plots in Figure 2, it is shown that all time-series variables are trending. The trends appear to be approximately linear. Thus, we specify linear deterministic trend in data in the cointegration test specification. The Johansen cointegration results are presented in Table 3. Trace and maximum eigenvalue statistics are used to determine the maximum rank, r. Using five percent critical value, maximum single rank is rejected for both statistics. This suggests the maximum rank to be two. The number of ranks indicates the number of cointegrating equations and ECT in a VECM.

Table 2 VAR lag order selection criteria

Endogenous variables: *LCP LEP LKP LXP LYP*
Exogenous variables: Constant
Included observations: 33

Lag	*LR*[a]	*FPE*[b]	*AIC*[c]	*SC*[d]	*HQ*[e]
0	NA	6.62e-10	-6.946912	-6.720168	-6.870619
1	243.9142	3.67e-13	-14.46562	-13.10516*	-14.00787
2	50.12728*	1.91e-13*	-15.22898*	-12.73480	-14.38977*
3	17.09326	4.35e-13	-14.71932	-11.09142	-13.49864
4	18.81928	8.40e-13	-14.77244	-10.01082	-13.17030

Note: * indicates lag order selected by the criterion.
[a] LR: sequential modified LR test statistic (each test at 5% level)
[b] FPE: Final prediction error
[c] AIC: Akaike information criterion
[d] SC: Schwarz information criterion
[e] HQ: Hannan-Quinn information criterion

Table 3 Johansen tests for cointegration of VAR(2)

Maximum rank	*Trace statistic*	*5% critical value*	*maximum-eigenvalue statistic*	*5% critical value*
0	96.121	68.52	47.657	33.46
1	48.464	47.21	32.975	27.07
2	15.489	29.68	9.161	20.97
3	6.328	15.41	5.899	14.07

Note: Linear trend and unrestricted constant are included in the model

Last, we estimate VECM using information obtained in previous tests. The results are summarized below where subscripts a, b and c respectively represent statistical significance of one, five and 10 percent levels,

$$\hat{\alpha} = \begin{pmatrix} -0.546^{b} & -0.018^{c} \\ -1.827^{b} & -0.113^{a} \\ 0.795^{c} & 0.020 \\ 0.053 & -0.029 \\ -1.419^{a} & -0.017 \end{pmatrix}$$

$$\hat{\beta} = \begin{pmatrix} 1 & 0.000 \\ 0 & 1 \\ -0.369^{a} & -6.081^{a} \\ -0.503^{a} & 9.548^{a} \\ 0.060 & -3.414^{a} \\ -6.814 & 70.474 \end{pmatrix}$$

$$\hat{\upsilon} = \begin{pmatrix} 0.030^{b} \\ -0.018 \\ 0.057^{a} \\ 0.067^{b} \\ 0.047^{c} \end{pmatrix}$$

$$\hat{\Gamma} = \begin{pmatrix} 0.448 & -0.018 & -0.278^{b} & 0.075 & -0.044 \\ 2.797^{c} & 0.007 & -1.276^{a} & 0.314 & 0.039 \\ 0.019 & 0.122 & -0.065 & -0.121 & -0.033 \\ -0.151 & 0.281 & -0.216 & -0.183 & -0.032 \\ 0.738 & -0.094 & 0.080 & -0.469^{b} & -0.036 \end{pmatrix}$$

Overall, the results of R^2 and χ^2 obtained for each equation show the model fit the data well. As determined above, the results of cointegrating equations are summarized in $\hat{\beta}$. To identify the free parameters of $\hat{\beta}$, Johansen (1995) argues at least $r^2 = 4$ restrictions are required. The restrictions are $LYP = 1$, $LKP = 0$ for the first cointegrating equation, $LYP = 0$ and $LKP = 1$ for the second. These restrictions imply that the presence of long-run relationship between LYP with LEP, LCP and LXP for the first equation and long-run relationship between LKP with LEP, LCP and LXP.

To check for model specification, four diagnostic tests are imposed. First, the LM test for residual serial correlation finds no evidence of serial correlation eventhough the lag is extended to 11. The residuals are also multivariate normal. Null hypothesis of normality is failed to be rejected for skewness, kurtosis and Jarque-Bera tests. Besides that, the homoscedasticity of residuals are also failed to be rejected for both joint and individual tests. Finally, we test for VECM stability to check whether the number of cointegrating equation is correctly specified. The VECM specification imposes three unit moduli since $r = 2$ and $K = 5$, thus there will be $K - r = 3$ unit eigenvalues. The result shows that the remaining muduli of eigenvalues are less than zero where all units lie within the unit circle. This result indicates the stability of VECM process and proves its specification to be correctly specified.

As per VECM results summarized above, the first cointegrating equation results show that LEP and LCP are statistically significant but LXP statistically insignificant. In contrast, for the second cointegration equation, LEP, LCP and LXP are found statistically significant. Since LYP in cointegrating equation is positive, any shock causes LYP to be higher than its equilibrium level. Then, this will force LYP to adjust downward towards equilibrium at speed of adjurstment of -0.546. Therefore, it takes two years to adjust to the equilibrium level. The adjustment is faster for LEP, but extremely slower for LCP. As compared to the second ECT,

LYP adjust very slowly. Besides, it takes almost nine years for LKP to adjust to the equilibrium level. The results also suggest that the first ECT dominates the second ECT.

4.3 Causality

Table 4 and 5 report Wald statistics of short-run and long-run Granger non-causality tests, respectively. Table 4 shows that there are significant unidirectional causalities running from *LYP* to *LKP*, from *LEP* to both *LYP* and *LKP*, and from *LCP* to *LXP*. These short-run causalities indicate individual significant short-run influence of particular variables on other variables.

If we refer to the VECM results, it is found that *LEP* negatively affects *LYP* and *LKP*. Though the direction of causality supports growth hypothesis where energy plays an important role in economic growth and capital accumulation, its negative sign produce a contradicting conclusion against the energy as an input of economic growth. Instead, the negative sign implies that the economy requires less energy consumption as the economy moves to less-energy intensive service sectors. This relationship is proven since the implementation of First Industrial Master Plan in 1986, Malaysia has focused on manufacturing sectors which is an energy-intensive sector. The sector grew from RM16 billion in 1987 to RM82 billion in 2005, measured at constant price (1987=100). However, service sectors (excluding government sector) grew larger from RM27 billion in 1985 to RM132 billion.[4] The negative sign also implies Malaysia has capacity constraints such that an increase in energy consumption cannot be absorbed by the economic sector. Other than that, it also signifies inefficient energy supply where many rural areas, specifically in Sabah and Sarawak, are lacks of energy supplies. Besides, it is also caused by inefficient energy use by unproductive sectors.

The negative effect is also observed in causal relationship between *LCP* and *LXP*. This suggests that reduction in *LCP* will increase export further. It indicates external demand trend by foreigners to restrict import of products that degrades the environment during manufacturing processes. Only *LYP* and *LKP* causality has positive relationship, in which an increase in the national income, increases the capital stock, not vice versa.

Those short-run signs contradict the long-run relationships presented by the error-correction equations. The equations exhibit $LYP = 0.369 * LEP + 0.503 * LCP$ and $LKP = 6.081 * LEP - 9.548 * LCP + 3.414 * LXP$, in which *LEP* positively affects both *LYP* and *LKP*, and *LCP* affects *LYP* positively. Using an alternative normalization, it is found that *LEP* and *LCP* significantly affect *LXP*. We also find that LYP affects LCP and LEP, and LEP affects LCP. Therefore, we can justify the long-run feedback effects between energy and economic growth, and emissions and economic growth, which are unseen in the short-run relationships.

[4] The data is easily available at http://www.statistics.gov.my.

Table 4 Short-run Granger non-causality test results/ Wald test results

Dependent variable	Independent variable				
	LYP	*LKP*	*LEP*	*LCP*	*LXP*
LYP	-	0.03	5.58**	0.44	0.23
LKP	3.22*	-	8.86***	0.58	0.01
LEP	0.00	0.47	-	0.36	0.04
LCP	0.02	1.27	0.54	-	0.02
LXP	0.67	0.20	0.10	3.84**	-

Note: The statistics are chi-squares of Wald tests.

Table 5 Long-run Granger non-causality and overall non-causality test results (running from all other variables to particular respective variable)

	Weak exogeneity test	*Overall exogeneity test*
LYP	5.75**	12.06*
LKP	10.65***	18.60***
LEP	3.78	13.20**
LCP	2.79	7.97
LXP	10.41***	14.56**

Note: The statistics are chi-squares of Wald tests.

Weak exogeneity test jointly examines the significance of ECTs. The Wald test results shows that there are long-run causal relationships between *LYP*, *LKP*, *LXP*, and their respective determinants, while *LEP* and *LCP* are not caused by other determinant in the long-run relationship. However, both *LEP* and *LCP* affect others. In addition, though there is no short-run relationship between *LXP* with *LYP*, *LKP* and *LEP*, the long-run relationship is, otherwise statistically significant. Furthermore, overall causal relationship is significant for all equation in VECM except *LCP*.

4.4 Generalised impulse-response function (IRF)

As discussed by Koop et al. (1996), we employ generalised impulse-response functions (IRF) to diagnose the causal effects discussed in Section 4.3. This method is immune to variable orderings in the VAR model as exhibited by traditional IRFs. The results are plotted as presented in the appendix. In contrast to IRF of VAR(p), IRF in a VECM model consists of two attributes. If the responses of respective variables to a shock bring the variables away from zero line, an equilibrium state, for some period and then bring back to equilibrium condition, the shock is transitory. On the other hand, if the shock brings the variables permanently away from the zero line, the shock is said to be permanent. The permanent shock is embedded in an $I(1)$ cointegrating equation while transitory shock comes from differenced variables.

The generalized IRFs show that the effects of shock do not die out completely after fifty periods. Though, the figures show that the shocks which are local to *LYP* and *LEP* have strong persistent effect on *LKP*. Overall the effects of shocks reduce after the sixth or seventh period, except the effects on *LXP* which are consistently strong as responses to shocks in *LYP*, *LKP*, *LEP* and *LCP*. This result indicates that export is endogenous to shocks of output, capital stock, energy use and emissions.

5. Conclusion and Policy implication

The causality results show that there is unidirectional causality running from energy to economic growth in Malaysia in the short-run relationship. In addition, there is no significant link to associate GHG emissions to energy use. In contrast, there are significant long-run bidirectional relationships between economic growth and energy use, and economic growth and emission. Though, energy use affects economic growth negatively in the short-run relationship, its long-run relationship exhibits a positive correlation. This finding contradicts previous studies by Yoo (2006) and Chiou-Wei et al. (2008), which found no-cointegration between economic growth and energy use. Our results support long-run results of Mahadevan and Asafu-Adjaye (2007), and both short- and long-run results of Ang (2008).

In contrast to Ang's finding, we consider the signs of coefficients for short-run and long-run equations. Our short-run finding complies with growth hypothesis, but the sign signifies that increases in energy reduce economic growth. There are some possible explanations for this situation. Payne (2010) argues that the negative correlation is due to all or any of these factors; capacity constraints of the economy, inefficiency in energy supply, excessive use in energy by unproductive sectors or structural economic moving to less energy intensive sectors. The growth hypothesis rules out any short-run conservation policies to be implemented in Malaysia, because the implementation of the policies will hurt the Malaysian economy.

However, our long-run results shows the policies may be implemented with long-run targets. Therefore, we recommend the policy maker to focus on improving the energy-economic growth relationship through developing internal economic capacity to utilize an increase in energy use and improving energy supply to whole nationwide where majority of eastern Malaysia suffers less energy supplies. The government should also focus on promoting energy saving practice by unproductive sectors. The practice should not be seen as part of the energy use reduction policy but as a policy to restructure energy supply to energy intensive industries. As one of signatory parties in the Kyoto Protocol, the empirical results however show that the conservation policies do not give immediate effects to Malaysian economy. And, thus it will to longer time for Malaysia to comply with emission reduction practice.

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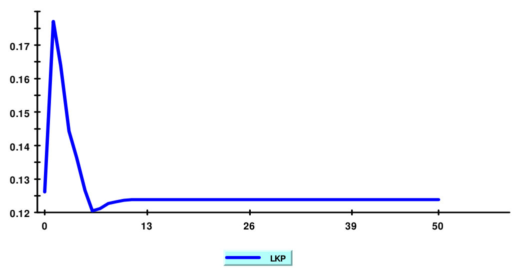
Appendix

Generalised impulse-response functions

Generalized Impulse Response(s) to one S.E. shock in the equation for LYP



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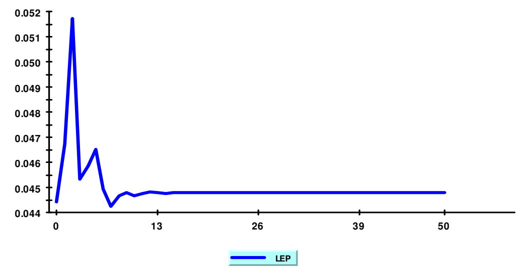

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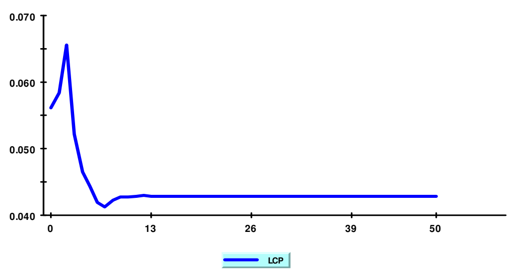

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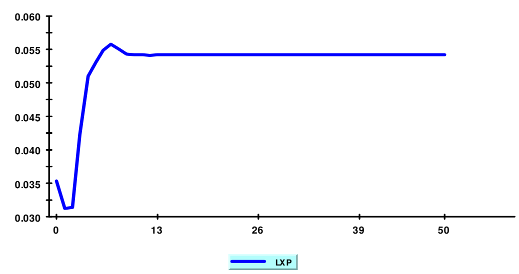
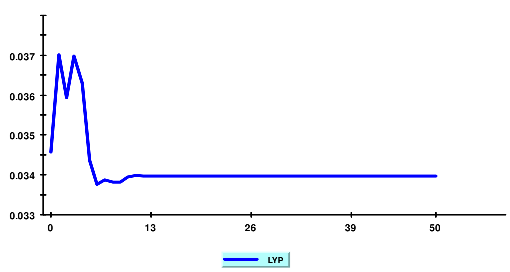


Generalized Impulse Response(s) to one S.E. shock in the equation for LKP



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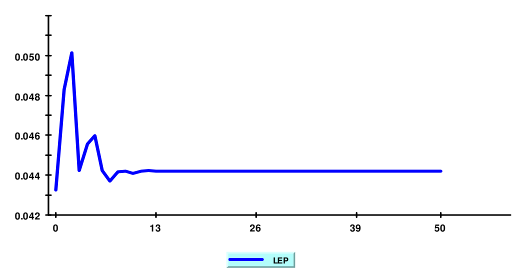

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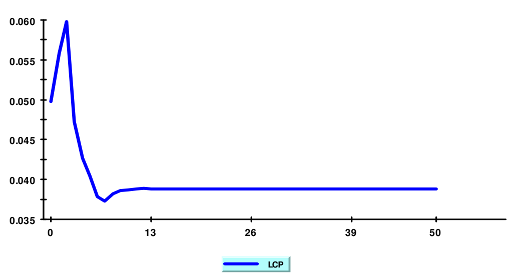

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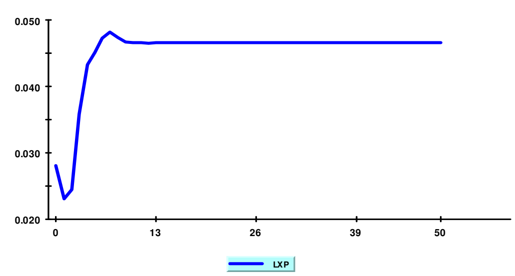
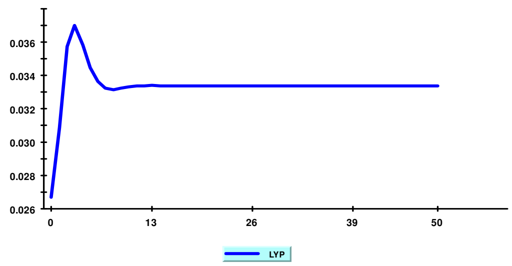


Generalized Impulse Response(s) to one S.E. shock in the equation for LEP



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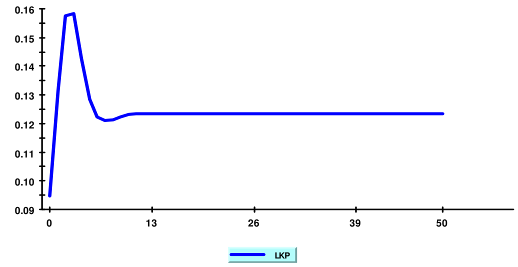

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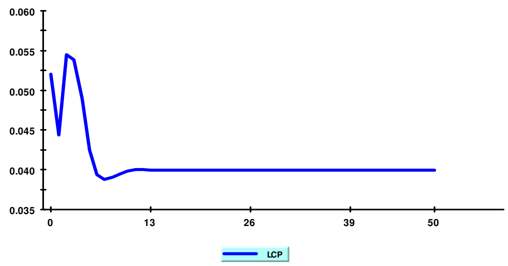

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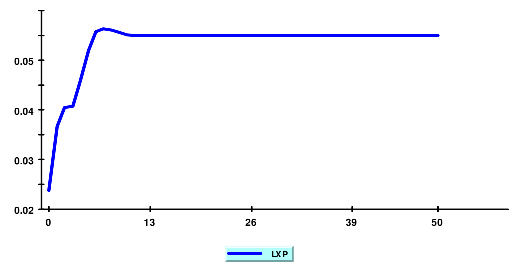
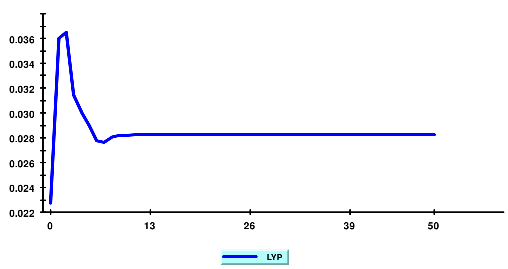


Generalized Impulse Response(s) to one S.E. shock in the equation for LCP



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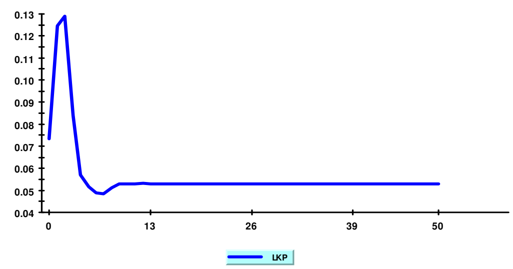

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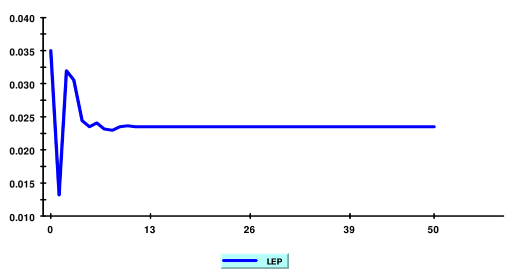

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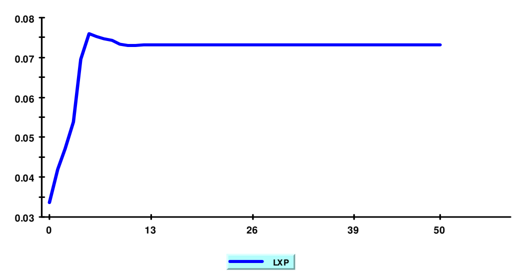
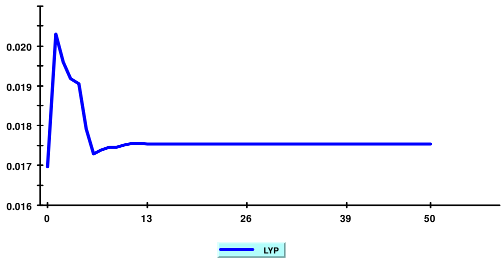


Generalized Impulse Response(s) to one S.E. shock in the equation for LXP



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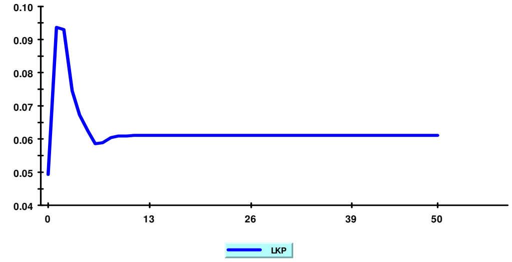

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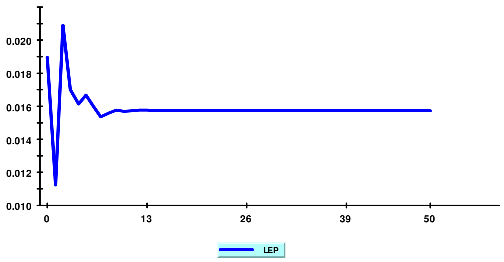

Generalized Impulse Response(s) to one S.E. shock in the equation for LXP