The Causal Relationship between GDP, Energy Consumption and CO_2 Emissions in Hong Kong

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ABSTRACT: This paper aims to explore the empirical result of the Granger causality relationship between GDP, energy consumption and CO_2 emissions evidence from Hong Kong covered period from 1965 to 2010. The results indicate that there is a unidirectional causality running from CO_2 emissions to energy consumption and CO_2 emissions to GDP in Hong Kong. Moreover, there is bidirectional causality between GDP and energy consumption existing. The findings suggest government to focusing on energy efficiency and renewable energy by promote public transportation, low carbon emissions car, impose tax on all fuel related activities and increase environmental friendly products and invest renewable energy infrastructure.

Keywords: Gross Domestic Product (GDP), Energy Consumption, CO_2 Emissions, Granger Causality, Hong Kong

1. Introduction

Climate change has been one of the most critical global environmental challenges which are the top priority in international political agenda (Pao and Tsai, 2011a). However, increasing economic activity reflects the level of energy consumption and CO_2 emissions (Sun, 1998). Hong Kong renowned as the world's fastest growing economies and stand as world's leading international financial center since low taxation and free trade were the major capitalist service economy (Bank for International Settlements, 2010). The government's views on recognizing local comparative advantages and liberalization policy since the late 1980 have encouraged the formation of a regional financial center which further enhances the rapid development of the newly-developed service industries (Tuan and Ng, 1999). As the nature of free market system, its economic growth heavily relies on international trade and finance which fluctuate according to the global economies.

There are a large number of research studies in economic and energy issue (Shahbaz et al., 2012; Wang et al., 2011; Apergis & Payne, 2010). The various results were generated by the different time periods, diverse countries and various variables. Previous studies have focused on the co-integration relationship between energy consumption and income for a few countries (Soytas and Sari, 2003). Nevertheless, there are few studies dedicating to analyze the connection of small economies as Hong Kong. This study aims to figure out proper economic growth policy and efficient energy policy in order to reduce carbon emissions and best utilize energy for both economies. The casual relations among Energy consumption (EC), CO_2 emissions (CO_2) and Gross domestic product (GDP) will be discussed in this paper.

2. Literature Review

There is a large amount of literatures explained the Granger causal relationship between energy consumption and economic growth by applying a multivariate framework in linear form (Belloumi, 2009; Lee & Chang, 2008; Narayan et al., 2008; Mehrara, 2007). The empirical results often contradict and vague (Pao and Tsai, 2011a). While the conclusion of most surveys pointed out that there is no consensus in the literature on these hypotheses but understanding the connection between variables is extremely significant due to effective energy policy implications mostly rely on causal relationship characteristic (Ozturk, 2010). The Granger causality between energy consumption and economic growth can be divided into four categories (Ozturk, 2010) as no causality between GDP and energy consumption (neutrality hypothesis), unidirectional causality running from economic growth to energy consumption (conservation hypothesis), unidirectional causality running from energy consumption to economic growth (growth hypothesis) and bidirectional causality between energy consumption and economic growth (feedback hypothesis) which each category provide different implications.

The study of output and energy nexus was pioneered by Kraft and Kraft (1987) they found a unidirectional causality running from GNP to EC evidence from USA for the period of 1947 to 1974. The results suggested that economic progress and output may be jointly determined due to the increase energy consumption, the increase economic development. Ho and Siu (2007) discussed about the macroeconomic impact on electricity policy in Hong Kong. The results showed a long run equilibrium relationship between real GDP and electricity consumption and a one-way causal effect exists from electricity consumption to real GDP. Soytas et al. (2001) found that there is a unidirectional causality running from energy consumption to GDP in Turkey. The empirical results indicated energy consumption positively affects GDP which implied possible energy conservation program could damage economic growth in the long run. However, many literatures found bidirectional causality relationship existence between energy consumption and economic growth. Shahbaz et al. (2012) examined the relationship between energy consumption and economic growth in the case of Pakistan. The results indicated a long run relationship equilibrium and co-integration between renewable energy consumption, nonrenewable energy consumption and economic growth. However, there are large amount of studies indicated the mix of empirical results such as Chiou et al. (2008) investigated the relationship between energy consumption and economic growth in Asian newly industrialized countries as well as the U.S. The evidence showed a neutrality hypothesis for the United States, Thailand, and South Korea. Nevertheless, findings on Philippines and Singapore demonstrated a unidirectional causality running from economic growth to energy consumption while energy consumption may have affected economic growth for Taiwan, Hong Kong, Malaysia and Indonesia.

Testing the validity of the Environmental Kuznets Curve (EKC) hypothesis has been widely used to study the relationship between economic growth and environmental pollutions. The EKC hypothesis initial proposed and tested by Grossman and Krueger (1991) explained the relationship imitates as an inverted U-shaped which imply the level of environmental quality and economic development. Ozturk and Acaravci (2010) stated that there is no causal relationship between CO2 and GDP in Turkey. However, many studies found the existence of casual relationship between CO_2 emissions and economic growth. For example, Pao and Tsai (2011b) discovered bidirectional causality relationship and long run positive relationship between GDP and carbon emissions in Brazil. Chang (2010) and Halicioglu (2009) discovered bidirectional causal relationship between CO_2 and GDP.

Shahbaz et al. (2010) performed Granger causality test and EKC to explore the causal relationship in Pakistan. The evidence determined EC increases CO_2 emissions both in short and long run. Chang (2010) extended the previous study by employed multivariate co-integration Granger causality techniques to explore the correlations between carbon dioxide emissions, energy consumption and economic growth. The results indicated the existence of unidirectional causality running from EC to CO_2 emissions which is conformed to Zhang and Cheng (2009) findings. Conversely, Ozturk and Acaravci (2010) applied ARDL bounds approach of co-integration in Turkey. The results pointed out that there is no Granger causality between CO2 emissions per capita and energy use per capita.

3. Research Methodology

This section discuss about the process of analyzing data. First of all, Augmented Dickey-Fuller unit root test was employed in order to test the stationary of variable data. If the data is found to be stationary at level, it can test Vector autoregressive (VAR) model directly. In contrast, if the data set found to be non-stationary, the differencing should be taken in order to transform from non-stationary data to stationary data. Secondly, the proper optimal lag length should be determined in order to avoid the error as much as possible. Thirdly, co-integration test was performed in order to find long run and short run relationship equilibrium between variables. Lastly, the Granger causality test will be performed to analyze the direction of relationship between variable. Three different assumptions regarding stationary of time series of GDP, EC and CO_2 are examined as follows.

Model I: Trend and intercept

$$\Delta Y_t = \mu + \rho_0 Y_{t-1} + \eta T + \sum_{t=1}^{p} \rho_t \Delta Y_{t-1} + \varepsilon_t \tag{1}$$

Model II: Intercept

$$\Delta Y_t = \mu + \rho_0 Y_{t-1} + \sum_{t=1}^{p} \rho_t \Delta Y_{t-1} + \varepsilon_t \tag{2}$$

Model III: Neither time series nor intercept

$$\Delta Y_t = \rho_0 Y_{t-1} + \sum_{t=1}^{p} \rho_t \Delta Y_{t-1} + \varepsilon_t \tag{3}$$

Based on above three equations GDP, EC and CO_2 represent by Y_t. ΔY_t is the first difference of the variable Y_t, μ is intercept, T is time variable, p is optimum lag length for which the lagged value of variable is significant and ε_t is residual of time series. This paper applies ADF approach to test GDP, EC and CO_2 series separately.

To selected the proper lag, this study apply two of the most used information criteria which are the Akaike's information criterion (AIC) (Akaike, 1969), Schwarz information criterion (SIC) (Schwarz, 1978). To determine optimum lag length of ADF test, AIC and SIC values are presented as following:

$$\text{SIC} = \ln\left|\tilde{\Sigma}\right| + \frac{\ln T}{T}(\text{number of freely estir } \tilde{\Sigma} \text{ :d parameters}) \tag{4}$$

$$\text{AIC} = \ln\left|\tilde{\Sigma}\right| + \frac{2}{T}(\text{number of freely estimated parameters}) \tag{5}$$

Where $\tilde{\Sigma}$ is estimated covariance matrix and T is the number of observations. AIC and SIC provided consistence results however the result of SIC is the first priority to be selected since Monte Carlo experiments suggested that the SIC offers a potentially useful combination approach. In addition, SIC is slightly accurate than AIC according to the principal parsimony.

Engle and Granger (1987) has joint studied and stated that a linear combination of two or more non-stationary series may be stationary, if such a stationary linear combination exists, the series are considered to be co-integrated and long-run equilibrium relationships exist. The presence of co-integration among the variables rules out the possibility of 'spurious' regression (Belloumi, 2009). Hypothesis to be examined with Johansen co-integration test to be applied on this study are as follows:

H_0: There is no co-integration relationship between variables

H_1: There is co-integration relationship between variables

Based on above hypothesis, the rejection of null hypothesis when critical value less than statistical value imply that the co-integration are exist and moving together in the long run. Granger (1991) mentioned that even though a given set of series may be non-stationary, there may existence various linear combinations of the individual series that are stationary.

This paper applied multivariate co-integration approach to examine whether time series of GDP, EC and CO_2 exists among long-run equilibrium interaction. There are five different models for error correction of the multivariate co-integration test as follows :

Model 1: Y_t has neither intercept constant nor linear trend in Co-integration Vector.

$$\Delta y_t = \alpha\beta' y_{t-1} + \sum_{j=1}^{p-1} D_j \Delta y_{t-j} + \varepsilon_t \tag{6}$$

Model 2: Y_t has intercept constant without linear trend in Co-integration Vector, but it has linear trend without intercept constant in VAR.

$$\Delta y_t = \alpha\left(\beta' y_{t-1} - \gamma_2\right) + \sum_{j=1}^{p-1} D_j \Delta y_{t-j} + \varepsilon_t \tag{7}$$

Model 3: Y_t has both intercept constant and linear trend in Co-integration Vector, but it has neither intercept constant nor linear trend in VAR.

$$\Delta y_t = \gamma_1 + \alpha\left(\beta' y_{t-1} - \gamma_2\right) + \sum_{j=1}^{p-1} D_j \Delta y_{t-j} + \varepsilon_t \tag{8}$$

Model 4: Y_t has either intercept or linear trend in Co-integration Vector and in VAR.

$$\Delta y_t = \gamma_1 + \alpha\left(\beta' y_{t-1} - \gamma_2 - \delta_2 t\right) + \sum_{j=1}^{p-1} D_j \Delta y_{t-j} + \varepsilon_t \tag{9}$$

Model 5: Y_t has both intercept constant and linear trend in Co-integration Vector, but it has linear trend without intercept constant in VAR.

$$\Delta y_t = \alpha\left(\beta' y_{t-1} - \gamma_2\right) + \sum_{j=1}^{p-1} D_j \Delta y_{t-j} + \varepsilon_t + (\varepsilon_t + r_t) \tag{10}$$

Where, D_j is k × k matrix for every j = 1, 2, 3,⋯, P. r_1 and r_2 are intercept constants in CE.

Multivariate co-integration test was employed with five different models. If the series do not have co-integration or no long run equilibrium relation among time series, VAR model is applied to measure Granger causality test. In contrast, if there is equilibrium interrelation among the time series, VECM was used to examine Granger causality test. Haghighat (2011) suggested the trace test (λ trace) and maximum eigenvalue test (λ trace) statistics to determine the number of co-integrating rank based on the likelihood ratio test (LR) proposed by Johansen and Juselius (1990). A Vector Error Correction Model (VECM) can lead to a better understanding of the nature of any non-stationary among the different component series and can also improve longer term forecasting over an unconstrained model. If co-integration between them has been detected series, it means that there exists a long term equilibrium relationship between variable. Therefore, VECM is applied in order to evaluate the short run and long run properties of the co-integration series. Granger causality model of multivariate regression of this study are illustrated as follows:

$$GDP_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} GDP_{t-i} + \sum_{i=1}^{p} \alpha_{2i} EC_{t-i} + \sum_{i=1}^{p} \alpha_{3i} CO2_{t-i} + \mu_{1t} \tag{12}$$

$$EC_t = \beta_0 + \sum_{i=1}^{q} \beta_{1i} GDP_{t-i} + \sum_{i=1}^{q} \beta_{2i} EC_{t-i} + \sum_{i=1}^{q} \beta_{3i} CO2_{t-i} + \mu_{2t} \tag{13}$$

$$CO2_t = \delta_0 + \sum_{i=1}^{s} \delta_{1i} GDP_{t-i} + \sum_{i=1}^{s} \delta_{2i} EC_{t-i} + \sum_{i=1}^{s} \delta_{3i} CO2_{t-i} + \mu_{3t} \quad (14)$$

Where, GDP_t, EC_t and $CO2_t$ denoted GDP, energy consumption and CO_2 emissions time series. All three variables were examined by above equations respectively. p, q and s stand for each variable in the optimum lag periods, t represent the period, μ is the error value of each model equation, and α, β, and δ are the coefficient values of each variable. In addition, this study apply 10% significant level if p-value found to be less than 10% thus, it can reject null hypothesis which mean that X Granger-cause Y.

4. Empirical Analysis

This study employs the historical data covered periods from 1965 to 2010 in Hong Kong. The time series data were conducted by the World Bank Database for Gross Domestic Product (current US$) and BP Statistic Review of the World Energy for Energy Consumption (million tons oil equivalent) and CO_2 emissions (million tons carbon dioxide).

4.1 Unit root test for GDP, EC and CO_2

Augmented Dickey Fuller unit root test is the first step to be performed in order to test the stationary of GDP, EC and CO_2. Tables 1 illustrate the results of ADF unit root test of Hong Kong and above result indicate that all variables tested in Hong Kong are stationary at the first differences I(1). It implies that these data sets do not contained unit root. Therefore, it can reject the null hypothesis since p-value is less than critical value (significant level at 10%).

Table 1 The Results of ADF Unit Root Test of Hong Kong

Test Statistic /Assumption	Level			First Difference			Concl-usion
	HK_GDP	HK_EC	HK_CO2	HK_GDP	HK_EC	HK_ CO2	
Trend & Intercept (p-value)	-2.07967 (0.5424)	-2.13645 (0.5121)	-2.09729 (0.5332)	-4.07799 (0.013**)	**-4.80033 (0.0024***)**	-8.63057 (0.000***)	I(1)
Intercept (p-value)	0.778381 (0.9925)	3.318135 (1.0000)	0.801412 (0.993)	**-3.78352 (0.0059***)**	-7.80132 (0.0000***)	**-8.29768 (0.0000***)**	I(1)
None (p-value)	2.137644 (0.9912)	3.43816 (0.9997)	3.433128 (0.9997)	-2.69268 (0.0082***)	1.90586 (0.0549*)	-1.70394 (0.0835*)	I(1)

Notes: *, ** and *** indicate the rejection of the null hypothesis at 10%, 5% and 1% level of significance, respectively

4.2 Optimal Lag Length Selection Results

Optimal lag length is necessary to define autoregressive time series and a residual in the process of ADF unit root test. Table 2 illustrates the optimal lag length criteria for Hong Kong.

Table 2 The Optimal Lag Length of GDP, EC and CO_2 in Hong Kong

Optimal Lag length					
	0	1	2	3	4
AIC	116.5877	109.5028	108.8446	108.548	107.7813*
SIC	116.7118	109.9992	109.7134	109.7892	109.3949*

* indicates lag order selected by the criterion
AIC: Akaike information criterion
SIC: Schwartz Bayesian information criterion

According to the table 2 the fourth lag was the most suitable for further process due to both AIC and SIC indicated the lowest value as 107.7813 and 109.394 respectively and its represents the accurately of analysis.

4.3 Co-integration Test for GDP, EC and CO_2

This paper employs Johansen's co-integration technique to indicate the relationship among three variables and find the most suitable model among five different models by concerning both Trace test statistic value and Maximum Eigenvalue test statistic since the local power of corresponding maximum eigenvalue and trace test is very similar (Helmut et al., 2001). Refer to Nieh and Lee (2001), they suggested to compare the trace test value with critical value by start from left to right and top to bottom. The model will be selected when the trace test value or Max Eigenvalue found to be lower than critical value. The results of Co-integration test in Hong Kong shown as table 3.

Table 3 Co-integration Test Results in Hong Kong

Rank Test (Trace)										
Rank	Model1		Model 2		Model 3		Model4		Mode5	
	Trace	10%	Trace	10%	Trace	10%	Trace	10%	Trace	10%
R=0	44.09372	21.77716	49.16929	32.26837	47.53635	27.06695	65.34306	39.75526	62.64737	32.06455
R=<1	**3.072428**	**10.47457**	7.848798	17.98038	6.555436	13.42878	19.58916	23.34234	16.89347	16.16088
R=<2	0.713377	2.976163	2.231472	7.556722	0.969561	2.705545	2.82056	10.66637	0.156829	2.705545
Rank Test (Max-Eigen)										
Rank	**Model1**		**Model 2**		**Model 3**		**Model4**		**Mode5**	
	Max-Eigen	**10%**	**Max-Eigen**	**10%**	**Max-Eigen**	**10%**	**Max-Eigen**	**10%**	**Max-Eigen**	**10%**
R=0	41.02129	15.71741	41.3205	20.05014	40.98091	18.89282	45.7539	23.44089	45.7539	21.8733
R=<1	**2.359051**	**9.474804**	5.617326	13.9059	5.585875	12.29652	16.7686	17.2341	16.73665	15.00128
R=<2	0.713377	2.976163	2.231472	7.556722	0.969561	2.705545	2.82056	10.66637	0.156829	2.705545

According to table 3 the trace test statistic in this study is smaller than critical value at Model 1 (3.072428< 10.47457) in the rank R≦1. The results confirm that there is long run equilibrium among three variables in Hong Kong since the null hypothesis is rejected and co-integration relationship exists. Besides, Maximum Eigen statistic value also reconfirm the significant at Model 1 (2.359051<9.474804) which indicate the same results with Trace test criteria.

4.4 Granger Causality Test for GDP, EC and CO_2

As results from previous section, VECM technique should be examined in this study since there is co-integration existence for Hong Kong. Table 4 shows the results of the vector error correction model (VECM) estimation, which is the forecast result. Then, table 5 will display the Granger Causality test results of Granger causality test performing by VECM approach.

The VECM integrating equation from the result can be written as

$$HK\_CO_{2\ t-1} = 2.279359\ HK\_EC(-1) + 0.0000574\ HK\_GDP_{t-1} \quad (15)$$

From above evidence indicates that there is a unidirectional causality running from CO_2 to EC and from CO_2 to GDP in Hong Kong. Moreover, the finding shows that there is bidirectional causality between GDP and EC.

However, the results from this study have conflict with previous literatures by Ho & Siu (2007) and Chiou et al. (2008) as they stated that there is only unidirectional causality relationship running from GDP to EC while the findings from this study supports the feedback hypothesis in Hong Kong. The reasons behind this conflict could be the difference of time series data used to analyze which Chiou et al. (2008) used the data period from 1954 to 2006 and Ho & Siu (2007) from 1966 to 2002. Besides, the finding reveals that CO_2 emissions level has an impact on energy consumption and GDP of Hong Kong which means that the more CO_2 emissions contribute into the atmosphere lead to the higher energy consumption and economic growth. The empirical results also indicate that economic growth and energy consumption have an influence on each other.

5. Conclusions and Suggestions

5.1 Causality Relationship of GDP, EC and CO2 in Hong Kong

The finding revels that there is a unidirectional Granger causality running from CO_2 to GDP and running from CO_2 to EC as well as bidirectional causality relationship between GDP and EC in Hong Kong. Overall evidences confirm that implementing energy conservation policy might lead to a significant negative impact on economic development. However, the empirical result from this study provided some conflicts with previous studies by Ho & Siu (2007) and Chiou et al. (2008) as they mentioned that there is only unidirectional causality relationship running from GDP to EC.

Table 4 The Results of VECM Model Estimation for Hong Kong

Variables	Dependent variables		
Independent variables (lag length)	GDP	Energy Consumption	CO_2 Emissions
CointEq1	1.169231	0.19566	-285.3044
D(HK_GDP(-1))	0.838666	0.00000795	-0.000163
D(HK_GDP(-2))	-0.714849	-0.000104**	-0.00016
D(HK_GDP(-3))	0.42054	-0.0000897**	-0.000409***
D(HK_GDP(-4))	0.232827	0.0000864**	0.000196*
D(HK_EC(-1))	-6890.817**	-0.12574	3.231089
D(HK_EC(-2))	2723.687	2.349553	3.454976
D(HK_EC(-3))	5383.971	1.47708	2.846551
D(HK_EC(-4))	-16087.11***	-2.820092	-6.81273*
D(HK_CO2(-1))	2334.391**	-0.03053	-1.5512
D(HK_CO2(-2))	-485.6119	-0.765557**	-1.552209
D(HK_CO2(-3))	-1212.13	-0.459623	-1.211181
D(HK_CO2(-4))	5803.051***	0.754467**	1.328629
R-squared	0.758244	0.5541	0.630666
Adj. R-squared	0.654635	0.362999	0.47238
S.E. equation	4.04E+09	798109.3	2569228
F-statistic	7.31829	2.899524	3.98434

Notes: *, ** and *** indicate the rejection of the null hypothesis at 10%, 5% and 1% level of significance, respectively

Table 5 The Granger Causality Test Result of Hong Kong performing by VECM Technique

Dependent	Independent	Chi-square	p-value	Result
D(HK_CO2)	D(HK_EC)	7.549854	0.1095	EC o CO_2
	D(HK_GDP)	6.177767	0.1863	GDP o CO_2
D(HK_EC)	D(HK_CO2)	8.831218	0.0655*	CO_2 → EC
	D(HK_GDP)	10.91018	0.0276**	GDP → EC
D(HK_GDP)	D(HK_CO2)	19.25067	0.0007***	CO_2 → GDP
	D(HK_EC)	12.55177	0.0137**	EC → GDP

Notes: *, ** and *** indicate the rejection of the null hypothesis at 10%, 5% and 1% level of significance, respectively. a. A o B: no causality between A and B b. A → B: unidirectional causality running from A to B

5.2 Policy Suggestion for Hong Kong

As mentioned above, energy consumption and CO_2 emissions play a significant role to GDP in Hong Kong. Therefore, the level of energy use is the key driver of economic growth. Nevertheless, energy is limited resource, and energy use is the main factor which creates greenhouse gas. Global warming becomes a sensitivity issue since protect environment may handicap the economic growth. As mention earlier that power generation, transportation and service sector are the main sectors that consumed energy and create CO_2 emissions thus, policy maker should pay attention on improve energy efficiency and conservation. Firstly, government should encourage people to take more public transportation, promote low carbon emissions car or impose tax on all fuel related activities so as to reduce CO_2 emissions which contribute into an atmosphere. Secondly, Government should improve and put more investment on energy efficiency infrastructure such as transform public transportation facilities to be energy efficient one to deduce CO_2 emissions, implement saving energy project. Thirdly, Rapid implement of renewable energy, energy efficiency and technological diversification of energy sources, would result in significant energy security and economic benefits (International Energy Agency, 2012). Although the set up cost of using renewable energy is higher but the renewable energy investment will pay off economically in the long run as it never run out. Besides, it doesn't emit greenhouse gases or atmosphere pollutants.

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