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Positive and Negative Effects of Research and Development

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ABSTRACT

This study aims to examine the effects of research and development expenditure on economic growth and carbon dioxide (CO_2) emission in the panel data for the period of 1996-2011 from five nations (Germany, Russian Federation, United Kingdom, United States and Canada). The panel co-integration was conducted and the results show that there is co-integrated relationship among the variables (research and development [R&D], gross domestic product [GDP], energy use and CO_2 emission). Then the fully modified ordinary least squares (FMOLS) test was performed and the findings explain that energy use and R&D are the determinants of GDP. Results from FMOLS show that energy use and R&D are the determinants of GDP. Energy use and GDP are the determinants of CO_2 emission. Results from dynamic ordinary least squares show that R&D is important to boost economic growth while energy use, GDP and R&D can have deleterious effects on CO_2 emission. Therefore, it is important to control the R&D expenditure to balance economic growth and environmental conservation.

Keywords: Research and Development, Economic Growth, Carbon Dioxide Emission
JEL Classifications: O32, Q40, Q50

1. INTRODUCTION

The issue on the effects of technology on economic growth has become a subject of intense interest and discussion among researchers worldwide. According to the Solow growth model, aggregate output hinges on input (labor, capital, and technology). Technology is vital to economic development, making businesses and industries become more dependent on it. Therefore, without technology, economic performance would change and could even become worse than before. The advent of technology in developed countries has desirable effects on their economies, such as attracting more investors, which enhanced their economic growth and made them competitive in the global world.

Research and development (R&D) is utmost important to ensure that we can have new technology. Firms will invest in R&D in order to produce more products at lower costs or new products that can be competitive in the market. An increase in the expenditure on R&D can help technology advancement. Therefore, R&D should be included in determining economic growth (Tuna et al., 2015). Griffith et al. (2000) stated that R&D is input for economic growth. Romer (1990) stated that new technology from R&D can prompt a rise in economic growth.

A rise in R&D can enhance technology which finally contributes to consuming more energy. The industrial sector requires much energy for economic activities. Without energy consumption, the sector would be crippled, and macroeconomic goals would not be accomplished. However, energy use produces carbon dioxide (CO_2) emission, ensuing environmental degradation (Apergis and Payne, 2009). Hameed (2011) added that the increase in energy and environmental problems are closely related, causing a hindrance to economic development (Fong et al., 2007). Therefore, this study aims to examine both positive and negative effects of R&D in developed countries.

Countries need to control the expenditure of R&D carefully to avert deleterious effects on the environment. Policies should be formulated to balance economic growth and environmental conservation. Governments should also play an important role in ensuring that all energy users, especially the industrial sector, comply with ISO 50001 or an equivalent energy management protocol (International Energy Agency, 2011).

2. LITERATURE REVIEWS

Several studies were done to examine R&D and economic growth such as Kokko et al. (2015), Ulku (2004) and Yanyun and Mingqian (2004). Kokko et al. (2015) examined the relationship between R&D expenditure and economic growth in the European Union (EU) and other regions. The study found that R&D can have desirable effects on economic growth in the EU countries. The results are consistent with the findings in other countries. However the effects are less in other industrialized countries. If comparing with the US country, the significance is much stronger that R&D expenditure can enhance economic growth.

Ulku (2004) investigated the relationship between innovation created in the R&D sectors and economic growth. The panel data approach was employed and data for 20 OECD countries and 10 non OECD countries for the period 1981-1997 were collected. The findings reveal there is a positive relationship between per capita gross domestic product (GDP) and innovation in both OECD and non OECD countries. Yanyun and Mingqian (2004) investigated the same relationship using the same approach and producing the same results but in different countries (8 ASEAN). The data period from 1994 to 2003 were collected. The study estimated the social rates of return to R&D and developed the evolution of R&D expenditure over the course of economic growth.

Several studies investigated the relationship between energy consumption, economic growth and CO_2 emission (Amin et al., 2012; Farhani and Rejeb, 2012; Dritsaki and Dritsaki, 2014, etc.) Amin et al. (2012) employed the Johansen co-integration method and the results show that there is a long run relationship among energy consumption, economic growth and CO_2 emission. The results of the Granger causality show that there is no relationship between economic growth and CO_2 emission and there is a relationship running from economic growth to energy consumption and from energy consumption to CO_2 emission. The results of the Granger causality test are different from Farhani and Rejeb (2012) as they found no significant relationship among energy consumption, economic growth and CO_2 emission.

Tiwari (2011) employed the vector error correction model to examine the relationship among energy consumption, economic growth and CO_2 emission for the period 1971-2005. The findings disclose that energy consumption produces CO_2 emissions, while economic growth has nothing to do with environmental problems.

Shaari et al. (2014) and Borhan et al. (2012) included the effects of foreign direct investment on CO_2 emission. Shaari et al. (2014) employed the panel data for the period 1992-2012 to investigate the effects in 15 developing countries. The panel co-integration results show that there are relationship among foreign direct investment, economic growth and CO_2 emissions. The fully modified ordinary least squares (FMOLS) results reveal that foreign direct investment does not affect CO_2 emissions but economic growth does. Borhan et al. (2012) used a longer period ranging from 1965 to 2010. The results indicate that foreign direct investment can contribute to increasing CO_2 emissions.

3. METHODOLOGY AND RESULTS

The panel data for the period of 1996 to 2011 from five nations (Germany, Russian Federation, United Kingdom, United States and Canada). This study used the panel unit root tests, panel co-integration tests, and panel FMOLS and panel dynamic ordinary least squares (DOLSs) estimators. This study was based on the following equation:

Table 1: Unit root results

Variables	Intercept		Intercept + trend	
	Level	First difference	Level	First difference
LLC test				
lnCO_2	1.71471	−4.4218*	2.15090	−7.70545*
	(0.9568)	(0.0000)	(0.98843)	(0.0000)
lnEU	3.27703	−7.30309*	1.30773	−8.52056*
	(0.9995)	(0.0000)	(0.9045)	(0.0000)
lnGDP	−5.54504	−3.82166*	−1.65887	−4.00419*
	(0.0000)	(0.0001)	(0.0486)	(0.0000)
ln$R\&D$	−3.52155	−3.57184*	−1.23966	−4.01826*
	(0.0002)	(0.0002)	(0.1075)	(0.0000)
IPS test				
lnCO_2	2.11307	−3.37046*	3.74760	−5.60209*
	(0.9827)	(0.0004)	(0.9999)	(0.0000)
lnEU	3.91892	−6.02645*	1.47755	−7.13499*
	(1.0000)	(0.0000)	(0.9302)	(0.0000)
lnGDP	−2.25063	−2.52727*	1.17091	−2.17720*
	(0.0122)	(0.0057)	(0.8792)	(0.0147)
ln$R\&D$	−0.45355	−2.59337*	−0.74946	−1.96519**
	(0.3251)	(0.0048)	(0.2268)	(0.0247)
ADF				
lnCO_2	4.03501	33.6854*	4.60048	45.8569*
	(0.9458)	(0.0002)	(0.9162)	(0.0000)
lnEU	1.17062	48.5708*	5.51107	52.1588*
	(0.9996)	(0.0000)	(0.8545)	(0.0000)
lnGDP	21.5279	21.9392**	6.79905	20.5781**
	(0.0177)	(0.0154)	(0.7443)	(0.0242)
ln$R\&D$	14.5907	23.3579*	14.7683	18.7000**
	(0.1477)	(0.0095)	(0.1407)	(0.0442)
PP				
lnCO_2	4.45284	63.1409*	5.25708	88.5985*
	(0.9246)	(0.0000)	(0.8734)	(0.0000)
lnEU	2.79505	58.5350*	10.7733	66.3989*
	(0.9858)	(0.0000)	(0.3754)	(0.0000)
lnGDP	54.2071	28.3119*	5.60908	27.0547*
	(0.0000)	(0.0016)	(0.8470)	(0.0026)
ln$R\&D$	15.2992	22.8624**	3.53894	30.0974*
	(0.1215)	(0.0113)	(0.9658)	(0.0008)

* and ** indicate the rejection of the null hypothesis of non-stationary at 1% and 5% significance level, respectively. In addition, P values are in brackets. R&D: Research and development, GDP: Gross domestic product, EU: European Union, ADF: Augmented Dickey and Fuller, PP: Phillips and Perron, LLC: Levin, Lin and Chu, IPS: Im, Pesaran, Shin, CO_2: Carbon dioxide

$$\ln CO_{2it} = \beta_{2t} + \beta_2 \ln Y_{it} + \beta_3 R\&D_{it} + \beta_4 EC_{it} + \varepsilon_{it}$$

Where, t is year, CO_2 is carbon dioxide emission which represents environmental degradation, Y is real GDP, EC is energy use and $R\&D$ is R&D expenditure which represents technology, ε is error correction term, β represents coefficient.

3.1. Panel Unit Root Results

The panel unit root tests based on augmented Dickey and Fuller (ADF), Phillips and Perron (PP), Levin, Lin and Chu (LLC) and Im, Pesaran, Shin (IPS) were conducted. LLC is to test the null hypothesis in panel versus the alternative of stationary when the cross-sectional units are independent of each other. The results of unit root tests are presented in Table 1. The unit root tests based on the LLC, IPS, ADF and PP were conducted to measure the stationary property of the time series data. The variables are non-stationary in level with the constant trend. However, in the first difference test, the results for all variables indicate that they are significant, which means all variables are stationary. The null hypothesis is rejected, and the alternative hypothesis is accepted. Thus, the Johansen co-integration test was then conducted.

3.2. Panel Co-integration Results

The panel co-integration test was used to see the existence of long run relationships among the variables. Suppose that there are relationships among the variables in the long, the variables move together over time. The equation is as follows:

$$\ln CO_{2it} = \beta_{1t} + \beta_2 \ln Y_{it} + \beta_3 \ln R\&D + \beta_4 \ln EC + \varepsilon_{it}$$

Where, $i = 1,\ldots\ldots N$ represents the panel member, $t = 1,\ldots\ldots$R&D refers to the time period, Y represents the economic growth, EC represents the energy use and β_i represents the slope coefficient. The parameters α_{it} and δ_i allow for possibility of country-specific effects and deterministic trend effects, respectively. ε_{it} represent the estimated residual deviations from the long-run relationship. The results from Table 2 are divided into individual intercept and individual intercept with trend and the results support the presence of a co-integrated relationship among the variables. Therefore, it can be concluded that there is a long run equilibrium relationship among CO_2, energy use, GDP and R&D.

3.3. FMOLS and DOLS Results

After conducting the panel co-integration test, there are several approaches that can be employed to see the long run relationship. This study employed the panel DOLS and FMOLS. The panel DOLS is less bias compared to the panel OLS and FMOLS. Table 3 shows the results of FMOLS and DOLS. Based on the FMOLS, it was found that energy use and R&D can have effects on GDP. Therefore, a 1% increase in energy use can increase 0.6% of GDP.

Table 2: Panel co-integration results

Variable	Intercept		Intercept + Trend	
	Statistic/P	Statistic/P	Statistic/P	Statistic/P
Within dimension				
Panel v-statistics	0.232191	−0.609414	−0.680536	−1.711122
	(0.4082)	(0.7289)	(0.7519)	(0.9565)
Panel rho-statistics	0.029507	−0.001863	0.697234	0.768349
	(0.5118)	(0.4993)	(0.7572)	(0.7789)
Panel PP-statistics	−2.528709*	−2.545456*	−3.039447*	−2.894406*
	(0.0057)	(0.0055)	(0.0021)	(0.0019)
Panel ADF-statistics	−2.650307*	−2.469045*	−2.585651*	−2.437451*
	(0.0040)	(0.0068)	(0.0049)	(0.0074)
Between dimension				
Group rho-statistics	1.006459		1.681897	
	(0.8429)		(0.9537)	
Group PP-statistics	−3.573190*		−5.549867*	
	(0.0002)		(0.0000)	
Group ADF-statistics	−2.760116*		−2.648248*	
	(0.0029)		(0.0040)	

* indicate the rejection of the null hypothesis of non-stationary at 1% and 5% significance level, respectively. In addition, P values are in brackets. ADF: Augmented Dickey and Fuller, PP: Phillips and Perron

Table 3: FMOLS and DOLS results

Variable	FMOLS		DOLS	
	Coefficient	t-statistics	Coefficient	t-statistics
Dependent variable=ln*GDP*				
ln*EU*	0.634827*	4.346511*	0.261419	0.643049
$\ln CO_2$	0.595435	4.023523	0.708688	3.066493
ln*R&D*	0.577322*	12.33378*	0.789141*	8.988138*
Dependent variable=$\ln CO_2$				
ln*EU*	0.986771*	17.79764*	0.820956*	58,373,107*
ln*GDP*	0.344026*	4.908869*	0.118661*	20,658,106*
ln*R&D*	0.015979	0.331389	0.056714*	17,319,041*

* indicate the rejection of the null hypothesis of non-stationary at 1% and 5% significance level, respectively. R&D: Research and development, GDP: Gross domestic product, EU: European Union, CO_2: Carbon dioxide, FMOLS: Fully modified ordinary least squares, DOLS: Dynamic ordinary least squares

A 1% increase in R&D can increase 0.5% of GDP. Nevertheless, CO_2 emission does not have any effect on GDP. Based on the DOLS method, it was found that R&D is statistically significant at 1%, suggesting that there is an effect of R&D on GDP. Therefore, a 1% increase in R&D can increase 0.7% CO_2 emission. The result also indicates that there are no effects of energy use and CO_2 emission on GDP.

In addition, the results of FMOLS also suggests that energy use and GDP can affect CO_2 emission. Therefore, a 1% increase in energy use can increase CO_2 emission by 0.9%. A 1% increase in GDP can also increase CO_2 emission by 0.3%. However, there is no effect of R&D on CO_2 emission. The results of DOLS suggest that energy use, GDP and R&D can affect CO_2 emission. Therefore, a 1% increase in energy use can result in an increase of 0.8% in CO_2 emission. Moreover, a 1% increase in GDP can also cause an increase of 0.1% in CO_2 emission. A 1% increase in R&D can cause an increase of 0.05% in CO_2 emission.

4. CONCLUSION

This study aims to examine both positive and negative effects of technology in developed countries (Germany, United Kingdom, France, United States, and Canada). Panel unit root, Pedroni Residual co-integration, FMOLS, DOLS, and Granger causality tests were conducted. Results from the panel unit root test show that all the variables used are non-stationary at level and stationary at first difference. Results from the panel con-integration test show that there is a long run relationship among the variables. Results from FMOLS show that energy use and R&D are the determinants of GDP. Energy use and GDP are the determinants of CO_2 emission. Results from DOLS show that R&D is important to boost economic growth while energy use, GDP and R&D can have deleterious effects on CO_2 emission. This finding is important for policy implications. The expenditure on R&D should be controlled to ensure that environmental degradation can be reduced and economic growth can still be increased.

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