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AicE-Bs2022KotaKinabalu
https://www.amerabra.org

10th Asia-Pacific International Conference on E-B Studies
The Magellan Sutera Resort, Kota Kinabalu, Sabah, Malaysia, 07-08 Sep 2022

Impact of Technological Advancements on Environmental Degradation: Evidence from ASEAN

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Abstract
This research investigates the long-run and short-run effects of technological advancements on environmental degradation in ASEAN countries. The research was conducted using Pooled Mean Group (PMG) panel data estimation methodologies, and the data set used in this study includes annual data from 2000 to 2019. Results revealed that the development of technology reduces the environmental degradation of ASEAN countries. Improvements in technology and more money for research and development through domestic savings lead to increased environmental quality in the long run. Therefore, this study concludes that policymakers should increase the investment in technological innovations to reduce environmental degradation.

Keywords: Economic Growth; Environmental Degradation; Technological Advancements; Pooled Mean Group

DOI: https://doi.org/10.21834/ebpj.v7i21.3671

1.0 Introduction

1.1 Background of the study

The development of technology has completely changed how we live. However, global economic appraisal trends showed that environmental degradation is frequently a side effect of progress. In such a situation, the nexus of technology is vital in augmenting environmental pressures. Moving towards sustainable economic goals and creating environmentally friendly policies have become the top priority in the last few decades. From the beginning of the nineteenth century, scholars have tried to investigate the factors affecting economic development. Endogenous growth in 1986 theory highlights economic growth as a sustainable development strategy many countries use to eradicate poverty and income inequality. Further, one of the key determinants of economic growth is the development of the industrial sector since one of the primary funding sources for the industrial sector is domestic savings. In addition, technological

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DOI: https://doi.org/10.21834/ebpj.v7i21.3671

development boosts productivity in the industrial sector and leads to economic development by reducing raw material usage and improving the efficiency and effectiveness of the operation sector (Zafar et al., 2019). However, high economic development through the industrial sector and non-monitored technological advancement generate many insoluble environmental issues for human and organism bodies (Khan et al., 2021). Engle's Law which Ernst Engle introduced in (1857) says rapid economic development leads to consuming luxurious goods and increases environmental degradation. This is because, with economic developments, people only need to spend a lower share of their income on necessary goods and can save more to consume high energy and luxury products. However, using these products is not environmentally friendly at all. Therefore, scholars have made a tremendous effort to identify the nexus between the economic growth of countries and environmental quality, and it has become a hot topic in the empirical literature.

Environmental Kuznets Curve (EKC) hypothesis (introduced in 1955 by Kuznets) shows that economic development contributes positively to environmental pollution until the country reaches the threshold level. Also, electronic dumping, carbon emission, and high energy usage make serious environmental issues (Shahbaz, et al. 2018). Therefore, scholars argue that most countries struggle to establish sustainable and eco-friendly development policies to meet both ends. In contrast, some researchers pointed out the other side of the coin and argued that economic development and technological advancement spur environmental adversity. They stand on the Halo hypothesis and explain that economic development and high technological advancement motivate people to shift to the eco-friendly consumption pattern and motivate the green technology innovations that eventually outweigh the environmental degradation (Zafar et al., 2019; Saud et al., 2018; Aydemir & Zeren, 2017). Hence, examining how technological development influences environmental quality is this study's key objective while considering how economic development, domestic savings, and urbanization support environmental degradation. Therefore, this study examines how ASEAN countries tackle the situation and investigates the nexus of economic development, domestic savings, urbanization, and technological advancements with environmental degradation. The rest of the paper consists of four sections. Section two discusses the literature review and then the methodology. Sections four and five show the empirical findings and conclusion with implications, respectively.

2.0 Literature Review

2.1 Effect of Economic Growth and Domestic Savings on environmental degradation

To begin with, since the early nineteenth century, scholars have made a tremendous effort to clarify how economic growth, domestic savings, and urbanization influence the environment and find the real association between these variables with environmental degradation. While one school of scholars points out that economic growth and domestic savings make a significant contribution to improving environmental quality (Khan et al., 2021; Zafar et al., 2019; Saud et al., 2018; Park et al., 2018; Shahbaz et al., 2018; Saidi & Mbarek, 2017). Another line of researchers holds a contradictory view and argues that economic growth and domestic savings bring many problems to the ecological system (Uzair Ali et al., 2022; Abid et al., 2022; Chishti et al., 2021; Ganda, 2020; Nasir et al., 2019; Salahuddin et al., 2018; Shahbaz et al., 2018; Behera & Dash, 2017; Khan et al., 2017). Depending on the demand following hypothesis, scholars argue that high economic development leads to sustainable financial development that lubricates the transfer of funds from the finance sector to the real sector and motivates domestic savings. As a result of high savings, a country can invest in research and development activities which leads to human capital development.

Furthermore, motivating green technology projects and allocating funds to promote eco-friendly innovations reduce wastage and improve productivity while declining the raw material requirement (Murshed et al., 2021; Liu & Song, 2020; Sulaiman & Abdul-Rahim, 2020). However, the EKC hypothesis explains that economic development leads to environmental pollution. Because most countries use low-cost but high carbon emission energy sources for their production to minimize the cost and to reduce the product prices with an ambition to capture the foreign markets. Though using renewable energy sources gives a high return, in the long run, the initial cost of shifting towards renewable energy sources is quite expensive (Xu et al., 2021).

2.2 Influence of Technological Advancements on environmental degradation

Technological advancement is one of the vital factors causing environmental quality. Scholars claim that most of the technological developments in the industrial sector are focused only on improving productivity and efficiency and reducing production costs but do not focus on eradicating environmental adversity (Kong, 2021; Saud et al., 2018). Therefore, they point out that till the countries use eco-friendly raw materials, renewable energy sources, green marketing technologies, environmentally friendly transportation sources, and eco-friendly consumable products, the effect of technological advancements on environmental quality is negative (Murshed et al., 2021; Ganda, 2020). Scholars suggest that government should impose environmental protection rules for the industrial sector and develop policies to monitor the industrial sector and charge against environmental damage (Khan et al., 2021).

2.3 Effect of Urbanization on Environmental Quality

Though creating city centers and attracting people to them brings many economic advantages to the nations, the increasing urbanization without a proper town plan leads to many environmental issues. For example, lack of proper waste disposal mechanisms, increment in energy usage, and overpopulation in town areas create many social and environmental issues (Tang, 2022; Yang et al., 2022; Iheonu et al., 2021; Liu et al., 2022; Wang et al., 2021). One of the key issues is the unstoppable environmental pollution due to greenhouse gas emissions via factories, transportation systems, and garbage dumps. However, He and Zhang (2022) argue that if a country can have a proper ecological civilization and town development plans, such nations can lead to achieving sustainable development goals while protecting environmental quality. Hence, now scientists and sociologists are working together to find a solution to create eco-friendly town development strategies to overcome these issues.

3.0 Methodology

3.1 Data sources and description of variables

The sample period for the study was limited to 20 years (from 2000 to 2019) stands on the data available to measure the technology achievement index and it included 7 ASEAN nations: Brunei, Cambodia, Indonesia, Malaysia, Philippines, Thailand, and Vietnam. Table 1 shows the selected variables and the proxies used to measure each variable.

Table 1. Key Variables

Variable Name	Proxy and the calculation mechanism
Greenhouse gas emission (Gh_gas)	Total greenhouse gas emissions (kt of CO2 equivalent)
GDP growth (Gdp_grow)	GDP per capita growth (annual %)
Domestic savings (D_save)	Gross domestic savings (% of GDP)
Urbanization (U_pop)	Urban population (% of the total population)
Technological Advancement (T_adv)	Technology Achievement Index (TAI)

Source. Researcher developed

3.2 Model Specification

$$gh\_gas_{it} = \propto_0 + \propto_1 Gdp\_grow_{it} + \propto_2 D\_save_{it} + \propto_3 U\_pop_{it} + \propto_4 T\_adv_{it} + \varepsilon_t \quad (1)$$

Where; Gh_gas indicates the greenhouse gas emission while Gdp_grow, D_save, U_pop, and T_adv represent the economic growth, domestic savings, urbanization, and technological advancements, respectively while ε shows the error term. Since the study used panel data analysis with unrestricted specification, 'i' denotes the cross-sections, and 't' represents the respective period.

3.3 Model Construction

The three-panel ARDL models, Pooled Mean Group (PMG) (Pesaran et al., 1999), Mean group (Pesaran & Smith, 1995), and Dynamic Fixed Effect (Pesaran et al., 1999), were used in the study as the primary analysis tools to look at the relationship between explanatory and regressor variables over the short- and long-run.

3.4 Cross-sectional Dependency

The study used the Breush-Pagan (1980) LM test, Pesaran (2004) scaled LM test, Baltagi, Feng, and Kao (2012) bias-corrected scaled LM test, and Pesaran (2004) as its key methodologies because the choice of data analysis method depends on whether the data set contains cross-sectional dependencies.

3.5 Panel unit root test

The analysis results are more reliable when the best unit root test is chosen among the first and second generations. The data set contains a cross-sectional dependency. Hence panel unit roots tests with second-generation cross-sectional dependency were applied. The two main tests were the Cross-sectional Augment Dickey-Fuller test (CADF) and the Cross-sectional IPS test (CIPS). Suppose the dependent variable gets stationary at its first difference and the explanatory variables at either their level or the first difference. Suppose the dependent variable gets stationary at its first difference and the explanatory variables at either their level or the first difference. In that case, there are no restrictions to moving for panel ARDL techniques. Therefore, the study used Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effect (DFE) as key techniques.

3.6 Hausman Test

The study occupied the Hausman test to confirm the slope homogeneity and finalize the best-fitted model among PMG, MG, and DFE. If test results show that P-value more than 0.05, the study selects PMG as the most appropriate technique to present the relationship between explanatory and regressor variables (Othman et al., 2018).

4.0 Results

4.1 Descriptive Statistics

Table 2 presents insights into the variables. It presents the statistical position of the data set via mean and standard deviation, while minimum and maximum values show the distribution of data points. Further, Skewness and Kurtosis values highlight the dispersion of the data set. According to test results, it can be concluded that greenhouse gas emissions and economic growth show a negative tail while other variables show positive skewness. Furthermore, Gh_gas, U_pop, and T_adv show the Platykurtic distribution. Meanwhile, Gdp_grow and D_save show the platykurtic distribution.

Table 2. Descriptive Statistics

	N Stat	Mean Stat	Max Stat	Mini Stat	Std. Deviation Stat	Skewness Stat	Kurtosis Stat
Gh_gas	140	11.87299	13.78462	9.672816	1.288957	-0.536048	1.956182
Gdp_grow	140	3.597914	11.48496	-3.78452	2.656113	-0.737017	3.980718
D-save	140	31.08819	68.49762	5.95921	13.67249	0.766309	3.256196
u_pop	140	47.54913	77.942	18.586	18.57409	0.147125	1.877569
T_adv	140	0.34494	0.839195	0.000452	0.247416	0.367172	2.026281

(*Source. E-view results sheet*)

4.2 Correlation

Table 3 presents the correlation among the variables. Test results indicate that technological advancements and economic growth positively affect environmental degradation, while savings show an inverse correlation. Surprisingly urban population does not show a correlation with environmental degradation. However, the study still uses the urban population as one of the key variables because the empirical literature suggests that the urban population is one of the key factors influencing environmental degradation. Hence, it is recommended to test the variables multicollinearity to decide whether any variables can be removed from the model based on the multicollinearity issue.

Table 3. Pearson Correlation Matrix

		Gh_gas	Gdp_grow	D_save	U_pop	T_adv
Gh_gas	Pearson Correlation	1				
Gdp_grow	Pearson Correlation	0.242313**	1			
D_save	Pearson Correlation	-0.227327**	-0.621633**	1		
U_pop	Pearson Correlation	-0.051653	-0.630767	0.783406**	1	
T_adv	Pearson Correlation	0.142902*	-0.256199**	0.339351**	0.631462**	1

Notes: *. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

(Source: E-views output)

4.3 Multicollinearity Test

Table 4 shows the results for multicollinearity among the variables. It indicates that except for the urban population, all the other variables have VIF values well below the critical value (5) and the tolerance value well above 0.2. Further, the VIF value for the Urban population is 4.77, and the tolerance ratio is 0.2096 also can be accepted because it lies below the critical value. Therefore, the study confirms that there is no multicollinearity among the variables. Hence, the study proceeds with a cross-sectional dependency test.

Table 4. Multicollinearity Test

Variable	VIF	1/VIF
Gdp_grow	1.84	0.544743
D_save	3.02	0.331650
U_pop	4.77	0.209611
T_adv	1.91	0.524053
Mean VIF	2.88	

(Source. STATA/MP 14.0 output)

4.4 Cross-sectional Dependency

The study used Breush-Pagan's (1980) LM test, Pesaran's (2004) scaled LM test, Baltagi, Feng, and Kao's (2012) bias-corrected scaled LM test and Pesaran (2004) CD test to examine whether a cross-sectional dependency in panels and Table 5 shows the test results. The null hypothesis of these tests is "there is no cross-sectional dependency," which is tested against cross-sectional dependency. The table values confirm a cross-sectional dependency and suggest moving forward with second-generation unit root tests.

Table 5 – Cross-sectional dependency

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
Gh_gas	287.5598***	41.13107***	40.94686***	11.30158***
Gdp_grow	63.31235***	6.528937***	6.344726***	6.665574***
D_save	82.15526***	9.436461***	9.252251***	-0.806368***
U_pop	329.0172***	47.52808***	47.34387***	17.66959***
T_adv	296.8106***	42.55850***	42.37429***	17.06516***

***, ** and * show significance at the 1%, 5% and 10% levels, respectively.

(Source. E-views output)

4.5 Unit Root Test

Since there is a cross-sectional dependency in the panel data set, the study utilized the second-generation unit root tests of CIPS and CADF. The test results are shown in Table 6. CIPS statistics highlight that all the variables get stationary at their first difference while Gdp_grow and T_adv, are stationary at their level as well. Further, CADF confirms that all the variables except urban population are stationary at its first difference while T_adv gets stationary at its level as well. Therefore, it gives direction to follow the panel ARDL model to analyze the long-run and short-run effects.

Table 6 - Unit root test

Variable	CIPS		CADF	
	Level	First Difference	Level	First Difference
Gh_gas	-2.13361	-3.93784***	-1.61826	-3.09966*
Gdp_grow	-2.71852***	-5.71013***	-1.20357	-5.28610***
D_save	-1.32629	-3.99561***	-1.67925	-4.66518***
U_pop	-0.31374	-6.35528***	-0.18194	-1.47146
T_adv	-3.16773***	-4.32852***	-3.11411*	-5.05657***

***, ** and * show significance at the 1%, 5% and 10% levels, respectively.

(Source. E-views Output)

4.6 Panel data estimation

The study used the three-panel ARDL models of PMG, MG, and DFE to measure the short-run and long-run effects of Gdp_grow, D-Save, U-pop, and T_adv on environmental degradation, and the results are presented in Table 7. The Hausman test was carried out to identify the best-fitted model, and the results are shown in Table 8. Referring to Table 8, PMG was selected since the statics prove that best-fitted models present the influence of explanatory variables on the regressor. PMG technique assumes that the long-run coefficients are identical but get differ across the cross sections in the short run and heterogeneity bias and can identify the long and short-run effects with the convergence of the parameters. The results suggest that all the variables significantly affect environmental degradation in the long run. At the same time, domestic savings (D_save) and technological advancements (T_adv) also affect environmental adversity in the short run.

Furthermore, a one percent increment in economic growth results in the greenhouse gas emission (proxy to measure the environmental degradation) of carbon dioxide equivalent by 0.033. It means that when a country achieves economic development by one percent, they emit water vapor, carbon dioxide, methane, nitrous oxide, and ozone gas that cause to warmer the planet's atmosphere to by 0.033. Moreover, when the urban population increases by one percent, greenhouse gas emission increases by 0.34. As stated by Philip et al., 2021 and Baloch et al., 2019 have proved that high urbanization leads to many environmental issues. Interestingly, when the domestic savings increase by one percent, the environmental degradation decreases by 0.013. This may be because, in the long run, the improvement in domestic savings leads to a move toward renewable and eco-friendly energy sources. Khan et al. prove the same in 2022 stating that technological advancement motivates the use of renewable energy and recycling waste which leads to reducing dumping. In addition, improvement in technological advancement also results in the reduction of greenhouse gas emissions in the long run. Because with the development in technology, the wastage, and harmful gas emission gets reduced while production efficiency increases. However, in the short run, both technological advancements and domestic savings significantly affect environmental degradation. Because, in the short-run, countries are highly focused on economic development through the development in the industrial sector rather than concerned with environmental quality. Furthermore, the speed of adjustment (convergent coefficient) indicates that it takes more than two years to recover the environmental damage made by economic development and urbanization, while the benefit of domestic savings and technological advancements to improve the environmental quality gets diluted after two years.

Table 7 - Panel Cointegration

Dependent Variable (co2emi)	Mean Group (MG)	Pooled Mean Group (PMG)	Dynamic Fixed Effect (DFE)
LONG RUN			
Gdp_grow	0.0251217***	0.0342747***	0.0615559*
	(0.0059835)	(0.006053)	(0.0339899)
D_save	-0.0004482	-0.015337***	0.0043011
	(0.0070642)	(0.0025357)	(0.0094293)
U_pop	0.0207722	0.0332433***	0.019866
	(0.0231225)	(0.0030147)	(0.0197187)
T_adv	0.2742038	-0.3686047***	0.1756772
	(0.1975677)	(0.1093098)	(0.39222)
SHORT RUN			
Speed of adjustment	-0.7607125***	-0.3983228**	-0.0957556***
	(0.1599503)	(0.183418)	(0.0391814)
Gdp_grow	-0.007243***	-0.0046772	-0.0000861
	(0.0029348)	(0.0028524)	(0.0017262)
D_save	-0.0012529	-0.0047358*	0.0007599
	(0.0037194)	(0.0024295)	(0.0013211)

U_pop	0.881202		0.0534262
	(1.163925)	1.065573	(0.0386532)
T_adv	0.0798162	(1.020416)	0.025282
	(0.0699628)	0.2622721*	(0.0541858)
		(0.1512526)	
Number of countries	7	7	7
Number of observations	133	133	133

Notes: ***, ** and * show significance at the 1%, 5% and 10% levels, respectively. Values in parenthesis indicate the standard error

(Source. STATA/MP 14.0 output)

Table 8. Hausman Test

Test	Chi2 value	Probability value	Decision
MG vs PMG	6.61	0.1581	PMG is appropriate
MG vs DFE	0.00	1.000	PMG is appropriate

(Source. STATA/MP 14.0 output)

Based on the analysis results, it can be concluded that countries need to have a sustainable development policy and pay attention to an ecological civilization policy to reduce greenhouse gas emissions. In contrast, countries must consider improving their domestic savings and go for foreign direct investment sources to fund green technological innovation and research and development to introduce eco-friendly production techniques as equipment. Further, countries should develop strategies to shift the industrial sector based on economic development to the service sector and focus on promoting green consumption patterns. Also, environmental protection rules and regulations must be imposed to eradicate environmental degradation.

5.0 Conclusion

This study examined the long-run and short-run effects of economic growth, urbanization, domestic savings, and technological advancements on environmental degradation in ASEAN countries. The results revealed that all the explanatory variables significantly influence greenhouse gas emissions in the long run. Urbanization and economic growth show a positive relationship with environmental degradation, while domestic savings and technological advancements work in the opposite direction. However, only domestic savings and technological advancements show a relationship with environmental degradation in the short run. It's interesting to note that domestic savings and technology improvements in ASEAN nations improve greenhouse gas emissions in the short term but have the opposite effect over time. This finding suggests that significant domestic savings and technology breakthroughs help us shift toward environmentally friendly technologies and renewable energy sources.

Moreover, an increase in domestic savings facilitates research and development within the ASEAN countries, leading to improved environmental quality. The convergent coefficient value suggests that economies take more than two years to dilute greenhouse gas emissions through rapid economic development and urbanization. Furthermore, the benefit of domestic savings and technological advancements will remain only for less than three years.

Acknowledgments

The authors gratefully acknowledge the financial support received from the Faculty of Business and Management, Universiti Teknologi MARA.

Paper Contribution to Related Field of Study

The results of this study suggest the significance of technical progress and the need for stakeholders to take into account technological advancements to improve environmental sustainability.

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