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THE ROLE OF EDUCATION IN REDUCING ENVIRONMENTAL POLLUTION: A REVIEW

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Abstract:

Environmental pollution is a major global challenge that can adversely affect ecosystems and human health. In developing countries, the lack of awareness and inadequate sustainable practices exacerbate pollution levels, making it imperative to identify long-term solutions. Here, education plays a crucial role in addressing this issue by raising environmental awareness, encouraging sustainable practices, and shaping policy reforms. Despite the importance of education in driving environmental change, the precise impact of education levels and expenditures on reducing pollution remains underexplored, especially in the ASEAN region. This paper addresses this issue by examining how education mitigates environmental pollution, focusing on both the level of education and expenditure on education. Using data from ten ASEAN countries covering the period from 1980 to 2022, this study employs three statistical methods—quantile regression (0.5), FMOLS, and Robust OLS—to analyze the relationship between education and CO2 emissions. The results consistently show a negative relationship between CO2 emissions and education, as measured by educational expenditure in primary, secondary, and tertiary education. These findings suggest that investing in education, regardless of the level, has a significant and direct impact on reducing CO2 emissions. By fostering a well-educated and environmentally aware population, ASEAN countries can achieve substantial reductions in CO2 emissions, contributing to global efforts to reduce environmental pollution.

Keywords:

Environmental Pollution, Education, Education Expenditures, ASEAN

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Introduction

Environmental pollution remains one of the most pressing global challenges, adversely affecting ecosystems, human health, and economic productivity. The rise in industrial activities, particularly in developing regions like the ASEAN countries, has exacerbated pollution levels, calling for urgent and sustainable solutions. While technological innovations and regulatory frameworks have been widely explored, the role of education in mitigating environmental pollution has received comparatively less attention. Education has the potential to foster environmental awareness, promote sustainable practices, and influence policy reforms. By integrating environmental education across all levels of schooling, governments can cultivate environmentally conscious citizens capable of driving long-term environmental change.

In the ASEAN region, the issue of pollution is particularly acute due to the rapid industrialization and urbanization of member states. Countries such as Malaysia, Thailand, and Indonesia, while enjoying economic growth, are facing increasing levels of CO2 emissions and environmental degradation. Previous research has shown that education can be a powerful tool in addressing environmental challenges, but the specific impact of education and education expenditure on environmental pollution within the ASEAN context remains underexplored. Moreover, there is limited understanding of how educational investments at various levels—primary, secondary, and tertiary—contribute to reducing pollution through behavior change and technological innovation. Table 1 shows some background information on the use of renewable energy, primary education enrollment, and reliance on clean fuel and technology for cooking. The less developed ASEAN member namely Cambodia, Lao, and Myanmar has a higher percentage of usage of renewable energy as a percentage of total energy consumption. ASEAN members who are actively producing for exports have lower usage of renewable energy with Singapore at 0.9%, and Malaysia at only 5.8% in 2020 which implies possibly higher levels of environmental pollution since these countries are export-oriented. On the other hand, in terms of the use of clean fuels and technologies for cooking, Singapore scores 100%, Brunei 100%, Vietnam 96.1%, Malaysia 93.8%, Indonesia 86.9% and Thailand 85.1%. Other ASEAN countries show relatively high adoption of clean fuels and technologies for cooking except Lao PDR. Table 1 also shows the percentage of net enrollment in primary education where the rates are quite high for all ASEAN countries. This implies that schools may be one of the better avenues to educate children on sustaining the environment. This hypothesis, however, needs to be empirically tested.

Table 1: Use Of Renewable Energy, Population With Primary Reliance On Clean Fuel And Net Enrollment Rate In Primary Education For ASEAN Countries

Country	% Renewable Energy/Total Energy Consumption			% Population with primary reliance on clean fuels and technology for cooking			% Net enrollment rate in primary education		
	2010	2020	+/-	2013	2021	+/-	2013	2022	+/-
Brunei	0.1	0.1	-	100	100	-	93.5	93.2	↓
Cambodia	64.8	51.4	↓	16.4	44.5	↑	95.6	86.8	↓
Indonesia	36.0	22.0	↓	95.6	86.9	↑	95.6	97.9	↑
Lao PDR	64.9	49.9	↓	4.7	9.3	↑	96.8	98.1	↑
Malaysia	2.0	5.8	↑	96.9	93.8	↓	98.8	97.1	↓

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Myanmar	84.9	59.8	↓	15.7	43.5	↑	86.8	95.1	↑
Philippines	32.6	29.1	↓	41.8	48.0	↑	97.2	87.7	↓
Singapore	0.5	0.9	↑	100	100	-	99.6	99.4	↓
Thailand	22.8	20.8	↑	76.7	85.1	↑	100	100	-
Vietnam	34.6	19.1	↓	68.1	96.1	↑	96.6	99.1	↑

Source: UNstats – SDG Database; WHO (https:www.who.int/data/gho/data/themes/air-pollution/household-air-pollution); ASEANstats Database

Environmental pollution, if left unattended can have a significant impact on public health and eventually, the productivity of the workforce. Therefore, government intervention is crucial to mitigate the impact of pollution and curb the source of the pollution (Jiang et al., 2021). Education serves as one of the tools that can be used to curb environmental pollution. Environmental education for example provides awareness of the negative impact of pollution. Furthermore, education in general can promote technological innovation for more sustainable methods of production and more conscious consumption. Amongst other tools to reduce environmental pollution, education is one of the more effective tools to address this problem (Li and Ouyang, 2019; Liu et al, 2023; Tang et al., 2023).

Given these issues, this paper seeks to address this gap by examining the relationship between education, education expenditure, and environmental pollution across ten ASEAN countries from 1980 to 2022. The study employs three statistical methods—quantile regression (0.5), Fully Modified Ordinary Least Squares (FMOLS), and Robust Ordinary Least Squares (OLS)—to ensure the robustness of the results. The objective is to explore how education influences CO2 emissions and to provide empirical evidence on the role of education as a long-term policy solution for environmental sustainability. It is hypothesized that education should lower environmental pollution within the scope of ASEAN countries. These countries provide interesting insights into their growing population and manufacturing for consumption and export are the bloodline of these countries. Naturally, more production and consumption is bound to exert more pollution, put pressure on natural resources, and consequently, lead to environmental degradation.

This paper provides a significant implication for future directions in public policy and more in-depth research. One of the main findings of this paper is that environmental issues need immediate attention and environmental issues must be addressed quickly to prevent the aggravated impact of pollution. Expenditure on education may be a long-term policy since it would take a couple of years to educate and re-educate the public on environmental preservation. Nevertheless, in the short run, environmental projects can be a good platform to mitigate environmental pollution.

The next section overviews the relevant literature related to this study, followed by the empirical methods. The penultimate section presents the results and discussion and the final section concludes.

Literature Review

The intergenerational impact of environmental degradation and human well-being is one of the areas that need further investigation. Amongst others, the impact of education on reducing environmental pollution can be examined from various angles. First, a reduction in environmental pollution such as air pollution leads to cleaner air and improved living conditions, which subsequently foster healthier

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physical well-being. Numerous studies have established that air pollution is a significant contributor to adverse health conditions, such as respiratory diseases, metabolic disorders, and other lung-related illnesses (Deryugina & Reif, 20239). In addition, pollution can have negative psychological effects such as anxiety, sadness, depression, and risk aversion, amongst others (Dong et al., 2021; Zhang et al., 2017; Guo et al., 2024. Populations exposed to high levels of environmental pollution generally exhibit higher rates of illness, which in turn leads to increased absenteeism from work. This absenteeism negatively affects workplace productivity (Chen et al., 2019; Borgschulte et al., 2022). Moreover, pollution may also affect workers' cognitive functions where pollution can lead to lower attention, slower responsiveness, and information processing. As such, workplace productivity can be significantly affected (Chang et al., 2019; Guo et al., 2022; Guo et al., 2024; Grainger and Schreiber, 2019). In addition, air pollution is often associated with negative emotions such as anxiety, sadness, or even depression, which in turn, may affect investment or business expansion decisions (Dong et al., 2021; Zhang et al., 2017). A recent study by Guo et al. (2024) suggests that pollution may alter the mood of individuals which often leads to mood deterioration resulting in individuals becoming more risk-averse, misperceptions, and poor decision-making (Guo et al., 2024). Such mood deterioration may cause distortions in decision making which incline towards perceived negativity. Consequently, reduced productivity may lead to decreased potential earnings, thereby undermining potential GDP growth.

From an educational point of view, pollution has a detrimental effect on children's health (Balakrishnan and Tsaneva, 2021; Zhang et al., 2019; Guo et al., 2024) which inevitably affects their school attendance. Children who are frequently exposed to pollutants are more likely to suffer from illnesses that necessitate taking leave from school. These frequent absences hinder their academic progress, particularly in challenging subjects such as science and mathematics. Not only that, when children fall ill, parents would have to take leave from work to bring their children to the clinic or hospital and nurse them back to health. This means that parents would also take leave from work to take care of their sick children, reducing working hours and productivity of their workplace and their take-home income (Currie & Schmieder, 2009). In addition, pollution is also linked to lower psychological well-being, lack of attention during classes, reduced cognitive ability, and impaired decision-making (Liu et al., 2020). This disruption not only affects their immediate learning outcomes but can also have long-term consequences on their educational attainment and future career prospects.

Second, the role of education is to promote sustainable development through behavioral changes in consumption and production. The transmission mechanism of environmental education to sustainable development can be achieved via knowledge sharing and nurturing the students to practice what they have learned (Guo et al., 2024). Higher education investment is often associated with increase likelihood of academic success. The level of education and location acts as a mediator between investment in education and environmental pollution. Furthermore, the role of education expectations, financial circumstance and society's well-being plays a pivotal mediating role between education expenditure and the degree of environmental pollution. As such, education has a crucial impact on the accumulation of children's future human capital rendering investments in education for all levels beginning from pre-school to university. Furthermore, educational programs that emphasize the importance of environmental protection can play a crucial role in mitigating pollution. By raising awareness and fostering environmentally responsible behaviors from a young age,

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education can contribute significantly to the reduction of pollution and the promotion of public health. Soares et al. (2021) found that women and those with higher levels of education showed higher perceptions of environmental awareness and issues to mitigate environmental problems. Their study suggested that both public and private sectors should be encouraged to invest in environmental education via various avenues such as through school curricula, special environmental projects, media engagement or public science projects. In education can influence human being's attitude through education (Hartley et al., 2015; Oliveira et al., 2019). Public involvement in acquiring and dissemination of scientific knowledge can significantly assist more pro-environmental attitude and help reduce environmental pollution through behavioral control. Such behavioral control includes 'throw-away' culture especially with single use plastic and other packaging materials.

Arguably, upon attaining certain level of economic growth and development, more resources are channeled towards green production, sustainable environment and responsible consumption due to availability of fund as well as awareness. As more research and innovation are undertaken on the environment under the flagship of sustainability, circular economy, green economy, ESG, inter alia, the society will be motivated to preserve the environment and opt for more energy efficient methods due to better understanding of how production, consumption and other activities affect the environment and climate change (Faize & Akhtar, 2020; Short, 2009; Sinha et al., 2022). As such, education play a pivotal role in positioning long term environmental and climate policies, and measure to achieve the policies. Measures include government expenditure allocated for the environment and any climate-related project, programs, initiatives; rules and regulation related to enhancing environmental sustainability and curbing environmental degradation; green and responsible financing; modification of production process to incorporate circular economy and green production. In more recent studies, Zhao et al. (2024) shows how expenditure on education reduces air pollution via three mechanism namely composition effect, technique effect and income effect.

On the other hand, Xue et al. (2023) argue that government expenditure on education leads to financial pressure which in turn result in higher carbon intensity. However, this connotation may be true in the case of development expenditure such as in non-green industrial activities, investment in recreational and tourism; which consumes more energy and at the same time, emit more carbon dioxide. Although development leads to economic growth, more production and consumption means greater demand for energy and increase in waste. Use of energy places a huge pressure on natural resources and increase carbon dioxide emission. Arguably, the same circumstances may not apply to government expenditure on education.

Third, education propagates technological innovation. According to the theory of the 'knowledge spillover effect' (Zhao et al., 2019; Stolpe, 2002), knowledge re-creation and re-generation occurs during knowledge dissemination process which is through education. As knowledge accumulates and expands leading to innovation to improve technological process, spillover effect will take place including in terms of human capital accumulation. The spillover process from knowledge accumulation leads to greater efficiency of the normal usage of resources for production and consumption processes. Moreover, knowledge spillover is associated with higher incremental income which in turn increases the scale of production and eventually, leading to long-term economic growth. This proposition is in line with the New Economic Growth Theory postulated by Romer in 1986.

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Tertiary education and research centers are home to technological innovation. The green technology innovation helps to reduce pollution by minimizing carbon emissions using non-fossil fuel energy, optimizing the industrial structure and improving production efficiency. Innovations in green technology help create more sustainable air and water pollution monitoring, carbon footprint management, crops production, forest, green building, water management monitoring, mining and exploration, and weather monitoring and forecasting. For example, green building technology leverages on motion detectors, usage of RFID, access card readers, low-carbon residential development with green-lanes and many more. In China for example, technological innovation plays a pivotal role in expanding energy efficiency (Wang et al., 2021). These innovations would help countries worldwide pave the way towards achieving its net-zero target by 2050. The market size for global green technology is valued at USD16.48 billion in 2023 and is expected to grow to USD19.76 billion in 2024 with a CAGR of 20.9% annually (Fortune Business Insight, 2024).

In short, the efficacy of education in reducing environmental pollution needs further investigation as the level of economic development, size of economy, the level of pollution, the level of technological development, usage of technology and various factors may affect additional impact. Since the ASEAN countries houses approximately 671.7 million people and is the third-most populous region in the world, environmental pollution may be a critical issue if no significant intervention is undertaken soon.

Empirical Methods

This paper aims to estimate the impact of education on environmental pollution. The benchmark equation is based on Zhao et al. (2024) and expressed as follows:

$$ED_{it} = \beta_0 + \beta_1 Edu_{it} + \beta_2 GDP_{it} + \beta_3 Open_{it} + \beta_4 Pop_{it} + \beta_5 Patent_{it} + \beta_6 Internet_{it} + \varepsilon_{it} \quad (1)$$

where ED is environmental pollution proxied by carbon dioxide emission (*CO2*), *Edu, Open, Pop, Patent, GDP* and *Internet* represent education expenditure and level, the degree of openness captures the depth of exports and imports, population, registered patents, size of the economy, and internet penetration. GDP, openness, population, patent, and internet penetration serve as control variables in the estimation. The Environmental Kuznet Curve hypothesis postulates that the level of pollution depends on the size of the economy (Ouyang et al., 2019). In this study, real GDP is used as a proxy for the size of the economy and the intensity of the economic activities. Population is another main contributor to pollution since a higher population leads to more pollution (Chen et al., 2020). In addition, the use of the internet leads to higher electricity consumption, hence, positively contributing to higher pollution. The use of the internet also serves as a representation of the usage of technology. On the other hand, access to internet facilities is vital for environmental education, leading to better awareness of the detrimental effects of pollution and how to mitigate such problems. Patents represent the level of innovation and technology in a country. In addition, this study uses patents as a proxy for technological development in a country. It is expected that higher patents imply more breakthroughs in technology including environmentally friendly technology in production, consumption, recycling, green financing, and many more.

The analysis employs three different estimation methods which include the Quantile regression (0.5 quantile), Fully Modified Ordinary Least Squares (FMOLS), and Robust regression which serves as sensitivity analysis to ensure the robustness of the findings

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Data

This study covers ten (10) ASEAN countries from 1980 to 2022. The proxy used for education is divided into two major categories. First, the expenditure on education which is segregated into four (4) types: total expenditure on education, primary education expenditure, secondary education expenditure, and tertiary education expenditure. Since specific data on education environmental expenditure is currently not available on a consistent basis, the use of a more general educational expenditure should suffice to reflect the impact of education on environmental issues Furthermore, this paper incorporates the level of education (primary, secondary, and tertiary) to assess its influence on education. Specifically, this paper aims to investigate the potential impact of education on mitigating environmental pollution. The proxy for environmental pollution is carbon dioxide emission (CO_2) since this data is widely available consistently and is the major source of pollution.

Several control variables were used in the model based on Zhao et al. (2024). GDP is used to control for the size of the economy which can also be used as a proxy for the level of development of a country. Population is used to represent the level of pollution exerted in a country. Countries with higher populations is expected to pollute more compared to countries with lower populations since consumption will be greater in countries with higher populations vis-à-vis countries with lower populations. The level of trade openness as represented by the ratio of export plus import to GDP is used to reflect the level of pollution. Countries with higher openness signal higher pollution especially when these countries are exporting agriculture, manufacturing, and mining-based goods. Production of manufactured goods and agricultural products, for example, result in different types of pollution namely air and water pollution. Since the countries selected in our studies are generally developing countries, apart from Singapore, the use of green technology in production is extremely limited. Therefore, we expect a positive relationship between pollution and openness. In addition, we account for patents and internet usage as control variables since patents reflect the level of technology in a country where the higher the number of patents, the more advanced and cleaner the technology. The impact of the internet can be observed from two perspectives. Higher usage of the internet means higher electricity consumption, and since coal is still one of the raw materials to generate electricity, implies higher pollution. On the other hand, the internet especially social media users may come across activities, campaigns, or any content on environmental preservation. Once environmental-related issues become viral and reach public consensus, environmental preservation efforts may gain a foothold amongst the general public.

Results and Discussion

Tables 2 and 3 provide the preliminaries of the data which include the descriptive statistics and correlation. The skewness and kurtosis show no extreme values in the data. Correlations also rule out the possibility of multicollinearity with the highest correlation of 0.78. There is a strong negative correlation between CO_2 emissions and education expenditure, particularly at the tertiary level (correlation = -0.7870). This suggests that higher education expenditure is associated with lower CO_2 emissions, rendering further investigation using regression. Additionally, GDP shows a strong negative correlation with CO_2 emissions (correlation = -0.6794), suggesting that as countries develop economically, their pollution levels may decrease, potentially due to the adoption of cleaner technologies and more efficient production processes. Given these preliminary indications on the correlations between variables, regressions were applied to test the relationship between these variables.

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Table 2: Descriptive Statistics

	Mean	Max	Min	Std. Dev.	Skewness	Kurtosis
co2	0.2220	0.3627	0.0951	0.0861	0.2581	1.7854
edu_exp	86.7624	100.0000	58.3119	10.6664	-1.2055	3.7752
patent	4319.2630	8878.0000	26.0000	2443.1120	0.1809	2.4380
open	148.6519	379.0986	45.5121	100.0298	1.2406	3.5063
pop	1.7769	3.0160	1.0294	0.5201	0.2968	2.2201
internet	28.9109	80.9021	0.5300	25.6456	0.5750	1.9142
gdp	9.4953	17.0072	6.0437	3.1366	1.0644	3.1572
edu_primary	88.3066	100.0000	59.8191	9.7700	-1.1005	4.0218
edu_secondary	88.1467	100.0000	60.6889	11.0698	-1.2166	3.3860
edu_te_exp	21.0652	38.0352	5.3398	11.0326	0.3259	1.4183
edu_tertiary	83.4178	100.0000	48.5864	14.2470	-0.8188	2.8596
edu_pr_exp	30.5042	43.2862	21.4736	7.0781	0.5138	1.8929
edu_se_exp	38.9067	60.4589	20.2422	12.9676	0.1775	1.5864

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Table 3: Correlation

	co2	edu_exp	edu_primary	edu_secondary	edu_te_exp	edu_tertiary	edu_pr_exp	edu_se_exp	gdp	open	patent	internet
co2	1											
edu_exp	-0.6596	1										
edu_primary	-0.3887	0.7089	1									
edu_secondary	-0.5508	0.7528	0.7132	1								
edu_te_exp	0.3852	-0.3976	-0.3666	-0.2822	1							
edu_tertiary	-0.7870	0.7839	0.6677	0.7491	-0.4129	1						
edu_pr_exp	0.3809	-0.3398	-0.1792	-0.4046	-0.1542	-0.3059	1					
edu_se_exp	-0.2960	0.5056	0.4775	0.4425	-0.8007	0.4536	-0.2466	1				
gdp	-0.6794	0.2941	0.0656	0.2676	0.2208	0.3893	-0.5069	-0.3097	1			
open	-0.1253	-0.1701	-0.2710	-0.1502	0.7914	-0.0237	-0.1053	-0.7847	0.5151	1		
patent	-0.0502	-0.2009	-0.3529	-0.1560	0.6999	-0.1537	-0.4093	-0.6570	0.6519	0.6429	1	
internet	0.1522	-0.1805	-0.1647	-0.1011	0.6475	-0.1791	-0.0134	-0.6808	0.4668	0.7268	0.6957	1
pop	0.1081	-0.1918	-0.2290	-0.1714	0.5684	-0.0850	-0.3624	-0.1549	0.0104	0.5031	0.2084	0.2173

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Table 4a: Dependent Variable: CO2

Variable	Quantile (0.5)	FMOLS	Robust	Variable	Quantile (0.5)	FMOLS	Robust
edu_exp	-0.0028***	-0.0010***	-0.0031***	edu_pr_exp	-0.0023	-0.0004	-0.0032***
	(0.0005)	(0.0008)	(0.0003)		(0.0016)	(0.0016)	(0.0010)
patent	0.000	0.0000	0.0000***	patent	0.0000***	0.0000	0.0000***
	(0.000)	(0.0000)	(0.0000)		0.0000)	(0.000)	(0.0000)
open	-0.0007***	-0.0007	-0.0007***	open	-0.0003	0.0005	-0.0007***
	(0.001)	(0.008)	(0.0001)		(0.0030)	(0.0030)	(0.0001)
pop	0.0341**	0.0945	0.0318***	pop	0.0214	-0.0270	0.0608***
	(0.0128)	(0.0754)	(0.0070)		(0.0321)	(0.0340)	(0.0119)
internet	0.0028***	0.0003	0.0029***	internet	0.0020***	0.0008	0.0025***
	(0.0028)	(0.0009)	(0.0002)		(0.005)	(0.005)	(0.0003)
gdp	-0.0178***	-0.0087*	-0.0176***	gdp	-0.0279***	-0.0150***	-0.0234***
	(0.0030)***	(0.0040)	(0.0014)		(0.0053)	(0.0042)	(0.0027)
c	0.5610		0.5887**	c	0.3111**		-0.0004
	(0.4765)		(0.0275)		(0.1257)		(0.0050)

Table 4b: Dependent Variable: CO2

Variable	Quantile (0.5)	FMOLS	Robust	Variable	Quantile (0.5)	FMOLS	Robust
edu_se_exp	-0.0040***	-0.0001	-0.0045***	edu_te_exp	-0.0032***	-0.0015**	-0.0024***
	(0.0012)	(0.0012)	(0.0005)		(0.0011)	(0.0006)	(0.0008)
patent	0.0000**	0.0000	0.0000***	patent	0.0000***	0.0000*	0.0000***
	(0.0000)	(0.0000)	(0.0000)		(0.0000)	(0.0000)	(0.0000)
open	-0.0007***	-0.0009***	-0.0009***	open	-0.0001	0.0009***	-0.0001
	(0.0002)	(0.0003)	(0.0001)		(0.0003)	(0.0002)	(0.0001)
pop	0.0298	-0.0850**	0.0595***	pop	0.0152	-0.1001***	0.0110
	(0.0250)	(0.0318)	(0.0068)		(0.0293)	(0.0288)	(0.0089)
internet	0.0012***	0.0001	0.0019***	internet	0.0027***	0.0001	0.0025***
	(0.0004)	(0.0004)	(0.0002)		(0.0007)	(0.0005)	(0.0004)
gdp_ene	-0.0236***	-0.0197***	-0.0199***	gdp_ene	-0.0374***	-0.0223***	-0.0344***
	(0.0048)	(0.0037)	(0.0016)		(0.0041)	(0.0032)	(0.0025)
c	0.5535***		0.5258**	c	0.4840***		0.4708***
	(0.0450)		(0.0234)		(0.0584)		(0.0257)

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Table 4c: Dependent Variable: CO2

Variable	Quantile (0.5)	FMOLS	Robust	Variable	Quantile (0.5)	FMOLS	Robust
edu_primary	-0.0024***	-0.0038***	-0.0028***	edu_secondary	-0.0019***	-0.0013	-0.0021***
	(0.0008)	(0.0008)	(0.0005)		(0.0006)	(0.0007)	(0.0004)
patent	0.0000	0.0000***	0.0000***	patent	0.0000**	0.0000**	0.0000***
	(0.0000)	(0.0000)	(0.0000)		(0.0000)	(0.0000)	(0.0000)
open	-0.0007***	0.0042***	-0.0007***	open	-0.0007***	0.0013*	-0.0008***
	(0.0002)	(0.0008)	(0.0001)		(0.0002)	(0.0006)	(0.0001)
pop	0.0242	-0.4917***	0.0207***	pop	0.0270	-0.1611**	0.0406***
	(0.0203)	(0.0845)	(0.0078)		(0.0219)	(0.0592)	(0.0073)
internet	0.0029***	-0.0014	0.0033***	internet	0.0028***	-0.0002	0.0036***
	(0.0009)	(0.0008)	(0.0003)		(0.0008)	(0.0008)	(0.0036)
gdp_ene	-0.0223***	-0.0077	-0.0215***	gdp_ene	-0.0227***	-0.0117**	-0.0218***
	(0.0047)	(0.0041)	(0.0018)		(0.0036)	(0.0038)	(0.0018)
c	0.5815***		0.6217***	c	0.5153***		0.5189***
	(0.0683)		(0.0437)		(0.0611)		(0.0337)

Table 4d: Dependent Variable: CO2

Variable	Quantile (0.5)	FMOLS	Robust
edu_tertiary	-0.0026***	0.0003	-0.0023***
	(0.0005)	(0.0004)	(0.0003)
patent	0.0000*	0.0000	0.0000***
	(0.0000)	(0.0000)	(0.0000)
open	-0.0005***	0.0000	-0.0005***
	(0.0001)	(0.0006)	(0.0001)
pop	0.0179	-0.0142	0.0314***
	(0.0166)	(0.0422)	(0.0071)
internet	0.0022***	-0.0004	0.0023***
	(0.0005)	(0.0010)	(0.0003)
gdp_ene	-0.0190***	-0.0080*	-0.0199***
	(0.0034)	(0.0039)	(0.0020)
c	0.5590***		0.5169***
	(0.0494)		(0.0259)

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The regression results in Tables 4a to 4d examine the impact of different levels of education, and education expenditure, and other control variables on CO2 emissions. The analysis employs three different estimation methods namely Quantile regression (0.5 quantile), Fully Modified Ordinary Least Squares (FMOLS), and Robust OLS to test for the sensitivity of the results and to ensure the robustness of the findings.

The findings consistently demonstrate that education expenditure at all levels, primary, secondary, and tertiary has a statistically significant negative impact on CO2 emissions. For instance, in Table 3a, the coefficient for total education expenditure (edu_exp) is significant at 1% level at -0.0028 (Quantile) and -0.0031 (Robust OLS). This indicates that a 1% increase in education expenditure leads to a reduction in CO2 emissions by approximately 0.0028% to 0.0031%, depending on the estimation method used.
Similarly, specific expenditures on primary (edu_pr_exp), secondary (edu_se_exp), and tertiary (edu_te_exp) education also exhibit negative coefficients across all models. For example, the coefficient for primary education expenditure in the Robust OLS model is significant at 0.0032, further affirming the positive role of education in mitigating environmental pollution.

The negative relationship between education expenditure and CO2 emissions aligns with the notion that education enhances environmental awareness and promotes the adoption of environmentally friendly practices. Educated individuals are more likely to understand the consequences of pollution and take action to reduce their carbon footprint, whether through personal behavior changes or advocacy for cleaner policies.

The control variables included in the models provide additional insights into the factors influencing CO2 emissions. GDP consistently shows a negative relationship with CO2 emissions across all models, with significant coefficients ranging from -0.0176 to -0.0279. This suggests that as economies grow, they tend to adopt cleaner technologies, resulting in lower emissions—a finding that supports the Environmental Kuznets Curve hypothesis. The degree of trade openness (open) also exhibits a negative relationship with CO2 emissions in most models, although the magnitude of the effect is smaller compared to education and GDP. The coefficient for openness is significant in the Robust OLS model at 0.0007. This finding indicates that while greater trade openness may lead to increased economic activity and potential pollution, it also facilitates the transfer of cleaner technologies and practices, ultimately reducing emissions.

Patents, representing the level of technological innovation, generally show a positive but small impact on CO2 emissions, with most coefficients being statistically insignificant. This suggests that while we normally assume that technological advancements can contribute to pollution reduction, the relationship is not straightforward and may depend on the type of technology being developed. Some technology may, in fact, contribute to higher environmental pollution. Internet penetration (internet) shows a positive relationship with CO2 emissions, particularly in the Quantile and Robust OLS models. This result could be attributed to the increased energy consumption associated with higher internet usage, especially in countries where electricity is generated from non-renewable sources. However, the internet also plays a crucial role in disseminating environmental information and education, which could counterbalance its negative impact on emissions over time.

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Population (pop) has a positive and significant impact on CO2 emissions in several models, particularly in the Robust OLS estimation. The coefficient for population in the Robust model is significant at 0.0318, indicating that higher population levels lead to increased pollution, likely due to greater consumption and waste generation. This underscores the importance of managing population growth and urbanization to mitigate environmental degradation.

Discussion

The findings from this study provide evidence that education, particularly at higher levels, is a powerful tool in reducing environmental pollution. The consistent negative relationship between education expenditure and CO2 emissions across various models highlights the potential of educational policies to address environmental challenges. By investing in education, countries can foster a more informed and environmentally conscious populace, which in turn can drive demand for cleaner technologies and sustainable practices.

The negative relationship between GDP and CO2 emissions supports the Environmental Kuznets Curve hypothesis, suggesting that economic development initially leads to increased pollution, but eventually, as countries reach a certain level of income, they begin to adopt cleaner technologies and reduce emissions. This transition underscores the importance of integrating environmental considerations into economic planning, particularly in developing countries that are in the early stages of this curve. The role of trade openness in reducing emissions, albeit modest, suggests that globalization can have positive environmental effects by facilitating the spread of cleaner technologies. However, this effect is likely context-dependent, varying based on the nature of the goods being traded and the environmental regulations in place. The positive impact of internet penetration on CO2 emissions highlights the dual role of technology in both contributing to and mitigating environmental pollution. While increased internet usage may lead to higher energy consumption, the internet also serves as a critical platform for environmental education and advocacy. Policymakers should consider strategies to enhance the positive aspects of internet use, such as promoting online environmental campaigns and encouraging the development of energy-efficient technologies.

In conclusion, results on the impact of education and education expenditure are generally consistent in terms of signs despite the use of three different statistical methods. The findings indicate that there is a negative relationship between CO2 emissions and education, as measured by educational expenditure in primary, secondary, and tertiary education. These results suggest that investing in education, regardless of the level, has a significant and direct impact on reducing CO2 emissions. By fostering a well-educated and environmentally aware population, countries can achieve significant reductions in CO2 emissions, contributing to global efforts to address climate change. Future research should explore the specific mechanisms through which education influences environmental behavior, as well as the role of technological innovation in this process.

Conclusion

Environmental pollution is of major concern, especially in this era where preservation and ensuring sustainability of the environment is an important agenda. Environmental pollution not only disrupts the environment but also leads to various health and psychological problems. These problems, in turn, lead to absenteeism, and inability to focus on work which renders lower productivity and disrupts economic growth. To mitigate environmental pollution, various actions could be undertaken, including education of the general public on how to combat

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environmental pollution. This paper examines the impact of education on environmental pollution using carbon dioxide emission (CO2) as a proxy for environmental pollution. Education is divided into two main categories – school enrollment and education expenditure. School enrollment is further divided into primary, secondary, and tertiary education. On a similar note, government expenditure on education is segregated into primary, secondary, and tertiary expenditure on education. Our sample of countries focuses on ten (10) ASEAN countries where these countries are experiencing rapid development, especially in industries, hence, emitting considerable amounts of CO2.

To assess the direct relationship between environmental pollution and education, this paper presents three methods to ensure the robustness of the results. This paper employed quantile, FMOLS, and robust OLS to test the relationship between environmental pollution and education. Results show that education can help reduce environmental pollution regardless the method of analysis used. An important policy implication is that the government and private sector should continue to invest in education, preferably on environmental education to as education serve as an enabler towards other environmental initiatives and policies in the near future.

Based on the findings in this paper the following policy recommendations are proposed. First, environmental education should be included in the syllabus at every level of education – primary, secondary and tertiary as education is the basis that curate a person's future behaviour. Second, education expenditure should be extended to specifically address environmental concerns via the formal education platform. Education-environment expenditure could further enhance environmental awareness, especially on pollution reduction with hands-on classes on recycling, upcycling, and other waste management activities. Third, the government, in collaboration with private sectors, should promote green activities and innovation at university levels. Universities should serve as the home for prototype products of green-based technology and innovation. The '*University-at-factory'* mode of education should be brought up to the next level to promote more green technology innovation. Fourth, the strengthen technical innovation and technical exchange, the government should provide more grants and tax relief to local start-ups.

However, there are several limitations to this study. First, this study focuses on ASEAN countries, hence, the results cannot be generalized to other countries with different levels of development and infrastructure. Second, the study only uses secondary data where education level and education expenditure serve as the main proxy to examine the impact of education on pollution. For future research, collecting primary data via questionnaires and interviews on the effectiveness of education on pollution reduction may be the way forward to prove such propositions.

In conclusion, investment in education paves a better future for the environment as it affects the behavior and attitude of the citizens. Education is a process of learning, adapting, and practicing habits that could reduce environmental pollution. This includes recycling, choosing renewable energy options, and reducing CO2 emissions by choosing public transport instead of private cars. Coupled with adequate and appropriate regulation and government incentives, environmental education can further consolidate efforts to reduce environmental pollution.

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