The Impact of Circular Economy on Health and Education for Transforming Waste into Wealth in Southeast Asia

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ABSTRACT

The circular economy represents a transformative framework for sustainability, emphasizing resource efficiency, waste minimization, and regenerative systems. This quantitative study investigates the relationship between circular economy implementation and its effects on public health and educational outcomes in Southeast Asia. Using panel data from five ASEAN countries Indonesia, Malaysia, Thailand, Vietnam, and the Philippines covering the 2015–2023 period, multiple regression analysis was employed to examine the correlation between CE implementation indicators and key health and education variables. The results reveal a significant negative association between the CE Implementation Index and national health burden (β = -0.47, $p < 0.01$), alongside a positive association with educational infrastructure (β = 0.53, $p < 0.01$). Path analysis further indicates that 35% of the circular economy's influence on education is mediated through improved health conditions. The predictive model suggests that a 10% increase in CE implementation could reduce per capita healthcare expenditure by approximately USD 22.7 and enhance classroom availability by 5.3%. These findings underscore the need for integrated policy frameworks that harmonize environmental, health, and education strategies to advance sustainable development goals across Southeast Asia.

Keywords*: Circular Economy, Education, Health, Southeast Asia, Sustainability.*

ABSTRAK

Ekonomi sirkular merupakan kerangka transformasional menuju keberlanjutan yang menekankan efisiensi sumber daya, minimisasi limbah, serta pengembangan sistem regeneratif. Penelitian kuantitatif ini bertujuan untuk menganalisis hubungan antara penerapan ekonomi sirkular dengan dampaknya terhadap kesehatan masyarakat dan hasil pendidikan di kawasan Asia Tenggara. Menggunakan data panel dari lima negara ASEAN Indonesia, Malaysia, Thailand, Vietnam, dan Filipina selama periode 2015–2023, penelitian ini menerapkan analisis regresi berganda untuk menguji korelasi antara indikator implementasi ekonomi sirkular dengan variabel kesehatan dan pendidikan. Hasil penelitian menunjukkan adanya hubungan negatif yang signifikan antara Indeks Implementasi CE dan beban kesehatan nasional (β = -0.47; $p < 0.01$), serta hubungan positif dengan infrastruktur pendidikan (β = 0.53; $p < 0.01$). Analisis jalur mengungkapkan bahwa 35% pengaruh ekonomi sirkular terhadap pendidikan dimediasi oleh peningkatan kondisi kesehatan. Model prediktif menunjukkan bahwa peningkatan implementasi CE sebesar 10% berpotensi menurunkan pengeluaran kesehatan per kapita sebesar USD 22.7 dan meningkatkan rasio ketersediaan ruang kelas sebesar 5.3%. Temuan ini menegaskan pentingnya

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pengembangan kebijakan terpadu yang mengintegrasikan strategi lingkungan, kesehatan, dan pendidikan untuk mencapai tujuan pembangunan berkelanjutan di Asia Tenggara.

***Kata kunci**: Ekonomi Sirkular, Pendidikan, Kesehatan, Asia Tenggara, Keberlanjutan.*

INTRODUCTION

The Circular Economy (CE) offers a transformative framework for redefining how societies manage resources, moving away from the traditional linear "take-make-dispose" model toward a system that prioritizes resource efficiency, waste valorization, and closed-loop production cycles. As Raworth (2018) aptly notes, the circular economy "offers an opportunity not only to redefine how we use and dispose of resources but also to measure the tangible impact of this systemic change on human well-being and social development." While the environmental and economic benefits of circular economy such as reduced resource depletion and enhanced economic resilience have been extensively documented, its social implications, particularly on health and education outcomes, remain underexplored quantitatively. This research seeks to address this gap by examining the statistical relationships between circular economy implementation and key social indicators, specifically health and education, in five ASEAN countries: Indonesia, Malaysia, Thailand, Vietnam, and the Philippines, over the period from 2015 to 2023.

Southeast Asia faces pressing challenges in waste management, rising healthcare costs, and constrained education budgets, making the region a critical case study for exploring the social dimensions of the circular economy. Data from 2015 to 2023 reveal significant variation in waste, health, and education metrics across the five countries. Malaysia generates the highest solid waste per capita at 1.2 kg/day and leads in healthcare expenditure with USD 415.2 per capita, alongside a relatively higher recycling rate of around 30–35% in recent years. Thailand follows closely, with solid waste generation around 1.0–1.2 kg/day, a recycling rate of approximately 27–30%, and healthcare spending of USD 275–300 per capita. In contrast, the Philippines produces lower solid waste per capita (around 0.4–0.6 kg/day in urban areas) but has one of the lowest recycling rates (around 10–20%). Indonesia and Vietnam fall in between, with solid waste generation of 0.7–0.9 kg/day, recycling rates of 13–20% (Ng et al., 2023). Note that no standardized Circular Economy Implementation Index (0–1 scale) exists across ASEAN; progress is measured through policy frameworks and material circularity rates, which remain low regionally (ASEAN Secretariat, 2021; Emami et al., 2025). Education expenditure as a percentage of GDP ranges from approximately 3.5% in the Philippines to 4.5% in Malaysia, highlighting disparities in investment priorities (World Bank, 2024).

These variations suggest potential linkages between circular economy practices and social outcomes. Notably, countries with higher circular economy implementation indices, such as Thailand and Malaysia, also exhibit higher education expenditure and recycling rates, hinting at possible correlations. However, the nature of these relationships, whether direct or mediated by factors such as policy frameworks or economic conditions, requires deeper investigation to establish causality and understand underlying mechanisms (Andronicean et al., 2021). The adoption of circular economy principles in Southeast Asia has gained momentum, driven by growing awareness of the environmental consequences of unmanaged waste and the economic potential of resource reuse. For instance, Malaysia's circular economy roadmap, launched in 2020, sets a target of achieving a 40% recycling rate by 2025, while Thailand's bio-circular-green economy model integrates circular economy principles into its national development strategy (Wiesmeth, 2020). Despite these advancements, existing research has primarily focused on circular economy environmental and economic impacts, such as reductions in greenhouse gas emissions and job creation (Modarress et al., 2020; Aguilar et al., 2021; Sulich & Sołoducho-Pelc, 2022; Li et al., 2023). While some studies have explored the health benefits of improved waste management, quantitative analyses linking circular

economy implementation to health and education outcomes remain scarce (Singh et al., 2024).

The study examines the impact of circular economy implementation on health and education outcomes, and identifies mediating factors that explain these relationships. The findings are expected to provide an empirical foundation for integrated policy design that aligns environmental sustainability with social development goals in Southeast Asia. This study aims to fill this research gap by developing a quantitative model to investigate the relationship between circular economic implementation and health and education indicators in the five ASEAN countries. By analyzing data from 2015 to 2023, the research seeks to identify the strength of direct and indirect relationships and uncover mediating factors that connect circular economy practices to social outcomes. The findings are expected to provide an empirical foundation for designing integrated policies that align environmental sustainability with health and education goals, advancing the broader agenda of sustainable development in Southeast Asia.

LITERATURE REVIEW & HYPOTHESIS DEVELOPMENT

Circular Economy and Health

The circular economy is defined as a regenerative system that minimises resource inputs, waste, emissions, and energy leakage through slowing, closing, and narrowing material loops, integrating economic, environmental, and social dimensions and drawing on principles of industrial ecology, performance economy, and regenerative design (Zink & Geyer, 2019; Geissdoerfer et al., 2020; Kirchherr, 2022; Clift et al., 2022; Ghisellini et al., 2025). It offers substantial potential to reduce pollution and enhance public health, particularly through renewable energy, waste management, and waste-to-energy strategies that mitigate air pollution and climate change, while construction and industrial applications can cut emissions dramatically (Gallego et al., 2020; Cantzler et al., 2020; Velenturf & Purnell, 2021; Dincă et al., 2022; Yang et al., 2023; Elroi et al., 2023; Wiedenhofer et al., 2025). Life-cycle assessments confirm health co-benefits, including gains of nearly one healthy life-day per tonne of recycled plastic, yet transitions also carry risks, especially in food and plastics sectors and informal activities in LMICs, such as exposure to hazardous materials or altered contaminant levels in soil and food (Ferronato & Torretta, 2019; Wright et al., 2019; Hou et al., 2020; Jain & LaBeaud, 2022; Deeney et al., 2023; Scott & Wu, 2024). Consequently, comprehensive LCAs and integrated risk management are essential to avoid unintended consequences and maximise health, climate, and sustainability benefits (Haas et al., 2015; Korhonen et al., 2018; Morseletto, 2020; Niero et al., 2021; Ncube et al., 2023).

Empirical studies consistently demonstrate a significant positive relationship between circular economy implementation and improved public health outcomes. In China, circular economy pilot cities were associated with reduced incidence of respiratory diseases and cardiovascular diseases, whereas in urban India, circular economy-based waste management systems decreased the risk of waterborne diseases by 32% and generated annual healthcare cost savings of approximately USD 4.2 per capita (Wang et al., 2021; Singh et al., 2024). The World Health Organization highlights that the circular economy improves health primarily through reduced environmental pollution of air, water, and soil; decreased exposure to hazardous materials via safer product design and material substitution; and enhanced access to nutritious food through circular food systems. Despite this growing evidence of health benefits, most studies focus on high-income countries or large emerging economies such as China and India, while rigorous quantitative analyses specific to Southeast Asia remain limited.

H1: Circular economy implementation index has a significant effect on environmental health index.

Circular Economy and Education

Literature on the relationship between the circular economy and education is relatively more limited. Del Mar et al. (2021) analyzed the integration of circular economy concepts into higher education curricula in 15 European countries, showing substantial variation in pedagogical approaches and levels of integration. However, this study did not measure the impact of circular economic education on broader educational outcomes.

Kirrchher (2022) conducted input-output analysis to calculate the impact of circular economy implementation on budget allocation in 20 countries, including several Southeast Asian countries. They found that every 10% reduction in waste production correlated with a 1.2% increase in education expenditure as a percentage of GDP. This study highlights the indirect relationship between the circular economy and education through budget efficiency mechanisms and resource reallocation. Rabbi et al. (2024) investigated how educational facilities in developing economies can function as catalysts for Circular Economy practices, but they did not measure the reverse impact of Circular Economy on education indicators. This gap indicates the need for further research on the two-way relationship between the Circular Economy and education.

H2: Circular economy implementation index has a significant effect on educational infrastructure index.

Circular Economy, Health, and Education

While these studies provide valuable insights into the bilateral relationships between circular economy and health or education, research analyzing the three-way relationship remains very limited. Skene (2022) proposed a conceptual framework for integrating circular economy into health education curricula, but did not measure the empirical impact of such integration. The United Nations Environment Program report on Circular Economy in Southeast Asia mentions the potential positive impact of the circular economy on health and education, but does not provide a comprehensive quantitative analysis. Similarly, the Ellen MacArthur Foundation (2020) report on circular economy opportunities for urban and industrial innovation in Southeast Asia highlights potential social benefits, but its primary focus remains on economic and environmental aspects.

H3: Environmental health index mediates the relationship between circular economic implementation index and educational infrastructure index.

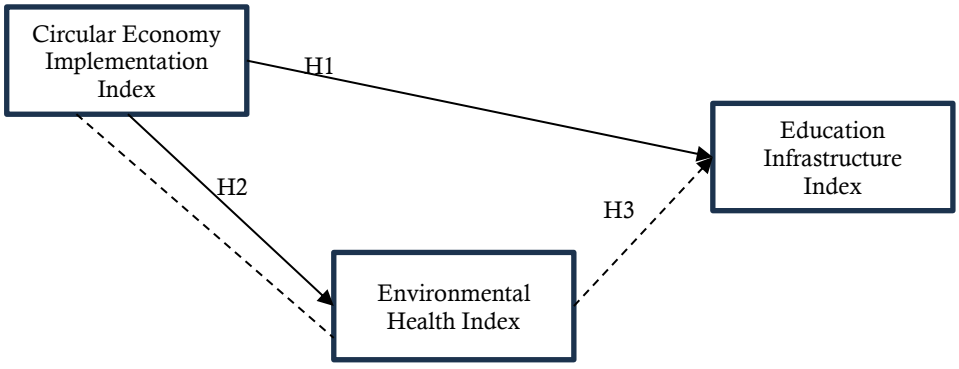

Figure 1. Conceptual Framework

Figure 1 presents the conceptual framework showing the influence of Circular Economy (CE) implementation on health and education outcomes in ASEAN countries. circular economy directly affects health indicators and education indicators, while Environmental Health (EHI) acts as a mediating variable linking the circular economy to educational outcomes. This framework highlights both direct and indirect effects of circular economy on human well-being through improved environmental and educational conditions.

RESEARCH METHODS

This study adopts a quantitative longitudinal approach, utilizing panel data from five ASEAN countries: Indonesia, Malaysia, Thailand, Vietnam, and the Philippines, spanning 2015 to 2023, resulting in 45 observations (5 countries × 9 years). This design enables the examination of temporal dynamics and cross-country variations in the impact of circular economy implementation on health and education outcomes. By leveraging a panel data framework, the study captures both time-series trends and country-specific factors, providing a robust foundation for analyzing the relationships between circular economy practices and social indicators in the Southeast Asian context.

Data were sourced from authoritative secondary databases to ensure reliability and comprehensiveness. Economic and education metrics were obtained from the World Bank development indicators, health data from the World Health Organization's Global Health Observatory, and waste and environmental management statistics from the United Nations Environment Programme (UNEP). These were supplemented by national reports from relevant ministries in each country and regional indicators from ASEANstats. To ensure consistency and comparability, data were rigorously cross-validated and, where necessary, adjusted using standardized methodologies, minimizing discrepancies and enhancing the accuracy of the dataset.

The primary independent variable is the Circular Economy Implementation Index (CEII), a composite index ranging from 0 to 1, adapted from methodologies by the Ellen MacArthur Foundation (2020) and Wang et al. (2021). The CEII comprises three weighted sub-indices: CE Policy (40%), evaluating national and local regulations on waste management, extended producer responsibility, and public procurement; Circular Economy Industry (30%), assessing industrial adoption of recycling, eco-design, and circular business models; and CE Consumer (30%), measuring consumer engagement in waste sorting, sustainable consumption, and product sharing or repair. Dependent variables are grouped into health indicators healthcare expenditure per capita (USD), morbidity rate of environment-related diseases (cases per 1.000 population), under-5 mortality rate (per 1.000 live births), and the Environmental Health Index (EHI, 0–100) and education indicators, including student-to-classroom ratio, primary school completion rate (%), education expenditure (% of GDP), and the Education Infrastructure Index (EII, 0–100). Control variables, such as GDP per capita, urbanization rate, population density, Human Development Index, labor force participation rate, Gini coefficient, and year dummies, were included to isolate CEII's impact.

Data analysis employed fixed-effects panel data models to account for temporal dynamics and country-specific heterogeneity, with Hausman tests confirming the suitability of fixed-effects over random-effects models to avoid bias from unobserved differences. To ensure robustness, sensitivity analyses were conducted, including testing alternative model specifications, using instrumental variables to address endogeneity, analyzing sub-samples across different time periods, and exploring alternative CEII definitions. These steps validated the consistency of findings across various conditions. All statistical analyses were performed using Stata version 17.0, with significance set at $p < 0.05$, ensuring accurate and reliable results.

RESULTS

Descriptive statistics for the main variables used in the analysis, aggregated for the entire sample (45 observations) and broken down by country. The data in Table 1 shows substantial differences between countries in key indicators. Thailand and Malaysia consistently have better values on most indicators, with the highest CEII (0.72 and 0.69, respectively), highest Environmental Health Index, and highest Education Infrastructure Index. Meanwhile, the Philippines consistently shows less favorable values on most indicators, with the lowest CEII (0.41), highest morbidity rate of environment-related diseases (64.4 per 1000), and lowest primary school completion rate (74.5%).

Per capita healthcare expenditure varies substantially, from USD 115.4 in Indonesia to USD 415.2 in Malaysia, reflecting differences in economic capacity and policy

priorities. Similarly, under-5 mortality rates range from 7.8 per 1000 live births in Malaysia to 35.3 in the Philippines, indicating significant disparities in healthcare quality and environmental conditions. On education indicators, student-to-classroom ratios vary from 24.3 in Malaysia to 42.6 in the Philippines, while education expenditure as a percentage of GDP ranges from 3.5% in the Philippines to 4.5% in Malaysia. Control variables also show substantial differences, with the highest GDP per capita in Malaysia (USD 11.782), more than four times that of Vietnam (USD 2.715), and urbanization rates ranging from 36.7% in Vietnam to 76.4% in Malaysia.

Table 1. Descriptive Statistics of Main Variables (2015-2023)

Variable	Overall Mean	Indonesia Mean	Malaysia Mean	Thailand Mean	Vietnam Mean	Philippines Mean
Circular Economy Implementation Index (CEII)	0.55 (0.13)	0.48 (0.08)	0.69 (0.07)	0.72 (0.05)	0.43 (0.07)	0.41 (0.06)
Health Indicators:						
Healthcare expenditure per capita (USD)	219.3 (121.5)	115.4 (18.7)	415.2 (45.6)	275.8 (32.1)	152.6 (24.3)	137.3 (19.8)
Morbidity rate of environment-related diseases (per 1000)	45.2 (15.8)	52.3 (8.4)	30.7 (5.2)	28.9 (4.7)	49.6 (7.3)	64.4 (9.1)
Under-5 mortality rate (per 1000)	18.6 (9.4)	21.5 (3.2)	7.8 (1.1)	8.5 (1.3)	19.7 (2.8)	35.3 (4.2)
Environmental Health Index (EHI)	68.3 (12.7)	63.7 (5.8)	82.4 (4.3)	79.8 (4.1)	65.2 (5.6)	50.2 (6.2)
Education Indicators:						
Student-to-classroom ratio	32.5 (8.7)	35.8 (4.2)	24.3 (2.8)	25.7 (3.1)	34.2 (3.9)	42.6 (5.3)
Primary school completion rate (%)	87.4 (8.2)	89.3 (2.5)	94.8 (1.7)	92.7 (1.9)	85.6 (2.8)	74.5 (3.6)
Education expenditure (% of GDP)	3.98 (0.56)	3.6 (0.32)	4.5 (0.27)	4.1 (0.24)	4.2 (0.31)	3.5 (0.29)
Education Infrastructure Index (EII)	65.3 (13.2)	58.7 (6.1)	79.8 (4.8)	76.3 (5.2)	62.1 (5.7)	49.4 (6.3)
Control Variables:						
GDP per capita (USD)	5.123 (4.891)	3.854 (412)	11.782 (1.342)	7.245 (785)	2.715 (387)	3.215 (428)
Urbanization rate (%)	52.7 (15.6)	55.8 (2.1)	76.4 (1.8)	50.2 (1.5)	36.7 (2.3)	44.5 (1.9)
Population density (per km²)	236.8 (237.6)	149.3 (4.7)	95.7 (3.2)	135.1 (2.8)	309.8 (5.1)	364.3 (6.4)
HDI	0.713 (0.063)	0.694 (0.012)	0.802 (0.009)	0.765 (0.011)	0.683 (0.014)	0.675 (0.013)

Table 2 shows that CEII has a significant impact on all health indicators analyzed. The negative coefficient in Model 1 (-227.35, $p < 0.001$) indicates that increased circular economy implementation is correlated with decreased per capita healthcare expenditure, suggesting the potential budget efficiency of circular economy implementation. Specifically, a 0.1 point increase in CEII (on a 0-1 scale) is associated with a decrease in per capita healthcare expenditure of USD 22.7, after controlling for other factors.

Model 2 shows that CEII negatively correlates with the morbidity rate of environment-related diseases (-35.74, $p < 0.001$), indicating that increased circular economy implementation is associated with a reduction in disease burden related to environmental factors. Similarly, Model 3 shows a significant negative correlation between CEII and under-5 mortality rate (-12.58, $p < 0.01$), while Model 4 shows a significant positive correlation with the Environmental Health Index (27.86, $p < 0.001$). Among control variables, GDP per capita and HDI consistently show significant influence on health

indicators, affirming the importance of economic and social development as determinants of health.

Table 2. Panel Data Regression Results (Fixed Effects) for Health Indicators

Variable	Model 1: Healthcare Expenditure per Capita	Model 2: Morbidity of Environment-related Diseases	Model 3: Under-5 Mortality Rate	Model 4: Environmental Health Index
Circular Economy Implementation Index (CEII)	-227.35*** (56.42)	-35.74*** (8.32)	-12.58** (4.21)	27.86*** (6.53)
GDP per capita (log)	135.27*** (32.15)	-8.48* (3.95)	-5.37** (1.82)	8.24** (2.95)
Urbanization rate	2.13* (0.98)	0.27* (0.12)	0.11 (0.08)	0.15 (0.14)
Population density	-0.02 (0.03)	0.01 (0.01)	0.00 (0.00)	-0.01 (0.01)
HDI	482.34** (173.26)	-87.42** (32.18)	-54.65*** (14.82)	95.73*** (22.64)
Constant	437.81** (156.28)	153.26*** (27.43)	73.42*** (15.37)	-24.35 (27.82)
Observations	45	45	45	45
R^2 (within)	0.73	0.68	0.64	0.71
F-statistic	47.28***	35.63***	29.47***	42.18***

*Note: Robust standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001; All models include country and year fixed effects*

Table 3 shows that CEII also has a significant impact on education indicators. The negative coefficient in Model 5 (-15.24, $p < 0.001$) indicates that increased circular economy implementation correlates with a decrease in student-to-classroom ratio, indicating an improvement in classroom availability relative to the number of students. Specifically, a 0.1 point increase in CEII is associated with a 1.52 point decrease in student-to-classroom ratio. Model 6 shows a significant positive correlation between CEII and primary school completion rate (16.85, $p < 0.001$), while Model 7 shows a more moderate positive correlation with education expenditure as a percentage of GDP (1.27, $p < 0.01$). Model 8 confirms a strong positive correlation between CEII and the Education Infrastructure Index (26.53, $p < 0.001$). As with health indicators, GDP per capita and HDI consistently show significant influence on most education indicators, affirming the importance of the broader socio-economic context.

Table 3. Panel Data Regression Results (Fixed Effects) for Education Indicators

Variable	Model 5: Student-to-Classroom Ratio	Model 6: Primary School Completion Rate	Model 7: Education Expenditure (% of GDP)	Model 8: Education Infrastructure Index
Circular Economy Implementation Index (CEII)	-15.24*** (4.37)	16.85*** (4.12)	1.27** (0.48)	26.53*** (5.78)
GDP per capita (log)	-4.82** (1.73)	3.56* (1.52)	0.24 (0.15)	5.37** (1.82)
Urbanization rate	-0.14* (0.07)	0.12* (0.06)	0.01 (0.01)	0.18* (0.09)
Population density	0.01 (0.01)	-0.00 (0.00)	0.00 (0.00)	-0.01 (0.01)
HDI	-42.35** (15.37)	57.82*** (16.24)	3.64* (1.57)	72.45*** (18.73)
Constant	82.37*** (21.34)	23.16 (18.73)	1.24 (0.97)	-32.48* (15.27)
Observations	45	45	45	45
R^2 (within)	0.65	0.69	0.53	0.74
F-statistic	31.26***	37.48***	18.73***	48.92***

*Note: Robust standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001; All models include country and year fixed effect*

One of the main hypotheses of this research is that the impact of circular economy implementation on education is partially mediated by improved health conditions. To test this hypothesis, path analysis was conducted using the Environmental Health Index

(EHI) as a mediator variable between CEII and the Education Infrastructure Index (EII). Table 4 presents the results of this mediation analysis.

Table 4. Path Analysis Results: Mediation of CEII Impact on EII through EHI

Path	Coefficient	Standard Error	p-value	95% CI
Total Effect (CEII → EII)	26.53	5.78	< 0.001	[15.20, 37.86]
Direct Effect (CEII → EII)	17.25	6.12	0.005	[5.25, 29.25]
Indirect Effect (CEII → EHI → EII)	9.28	3.42	0.007	[2.58, 15.98]
Proportion of Effect Mediated	0.35	0.14	0.012	[0.08, 0.62]

Note: Model controls for GDP per capita, urbanization rate, population density, and HDI; CI = confidence interval

Results in Table 4 show that of the total effect of CEII on EII (26.53), approximately 35% is mediated through EHI. This supports the hypothesis that part of the impact of circular economy implementation on education infrastructure works through improved environmental health conditions. The direct effect of CEII on EII remains significant (17.25, $p = 0.005$), indicating that circular economy implementation also has a direct impact on education infrastructure that is not mediated by environmental health. This may reflect other mechanisms, such as budget efficiency and increased resources for education investment.

Table 5. Path Analysis Model: Relationship between CEII, EHI, and EII

Relationship Between Variables	Coefficient (β)	Significance
CEII → EHI	27.86	*** ($p < 0.001$)
CEII → EII	17.25	** ($p < 0.01$)
EHI → EII	0.33	** ($p < 0.01$)
CEII → EII (Indirect Effect through EHI)	9.28	** ($p < 0.01$)

*Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; Model controls for GDP per capita, urbanization rate, population density, and HDI*

Table 5 illustrates this path model, showing the relative strength of direct and indirect paths. The path analysis results show that CEI has a strong and significant positive effect on EHI ($\beta = 27.86$, $p < 0.001$) and a significant effect on EII ($\beta = 17.25$, $p < 0.01$). EHI also significantly influences EII ($\beta = 0.33$, $p < 0.01$). Additionally, CEI exerts a significant indirect effect on EII through EHI ($\beta = 9.28$, $p < 0.01$). The mechanism for this indirect effect can be explained through several pathways. First, circular economy implementation reduces environmental pollution and exposure to hazardous waste, which in turn reduces the incidence of environment-related diseases. This disease burden reduction contributes to decreased student and teacher absenteeism, as well as improved cognitive capacity, both of which can improve education outcomes. Second, the reduction in public health burden can reduce healthcare expenditure at both household and government levels, allowing for resource reallocation to education investment, including infrastructure.

Table 6. Elasticities of CEII Impact on Health and Education Indicators by Country

Country	Elasticity of Healthcare Expenditure per Capita	Elasticity of Morbidity of Environment-related Diseases	Elasticity of Student-to-Classroom Ratio	Elasticity of Education Infrastructure Index
Indonesia	-0.32** (0.12)	-0.55*** (0.14)	-0.42** (0.15)	0.48** (0.17)
Malaysia	-0.18* (0.09)	-0.42** (0.13)	-0.28* (0.12)	0.31* (0.14)
Thailand	-0.25** (0.10)	-0.48** (0.15)	-0.35** (0.13)	0.37** (0.14)
Vietnam	-0.48*** (0.13)	-0.63*** (0.16)	-0.53*** (0.14)	0.57*** (0.15)
Philippines	-0.52*** (0.14)	-0.68*** (0.17)	-0.58*** (0.15)	0.62*** (0.16)

*Note: Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; Elasticity = percentage change in dependent variable associated with percentage change in CEII*

Table 6 shows an interesting pattern of heterogeneity. Vietnam and the Philippines consistently show higher elasticities (in absolute value) compared to other countries, indicating that the marginal impact of increased circular economy implementation on

health and education indicators is greater in these countries. This finding aligns with the diminishing returns hypothesis, which suggests that countries starting with lower levels of CE implementation tend to gain greater marginal benefits from improvements compared to countries that already have higher implementation levels.

Malaysia, which has the second-highest circular economy implementation level in the sample, shows the lowest elasticities for all indicators, affirming this "diminishing returns" pattern. However, even in Malaysia, elasticities remain statistically significant, indicating that even countries with relatively advanced circular economy implementation can still derive additional benefits from further implementation improvements. Based on the estimated regression models, predictive analysis was conducted to assess the potential impact of various scenarios of increased circular economy implementation. Table 6 presents projections of the impact of 10%, 20%, and 30% increases in CEII on key health and education indicators, assuming other variables remain constant.

Table 7. Projected Impact of Increased CE Implementation on Health and Education Indicators

Scenario	Change in Healthcare Expenditure per Capita (USD)	Change in Morbidity of Environment-related Diseases (per 1000)	Change in Student-to-Classroom Ratio	Change in Education Infrastructure Index
+10% in CEII	-22.7	-3.6	-1.5	+2.7
+20% in CEII	-45.5	-7.1	-3.0	+5.3
+30% in CEII	-68.2	-10.7	-4.6	+8.0

Note: Projections based on coefficients from fixed effects models, assuming other variables remain constant

Projections in Table 7 show that a 10% increase in CE implementation potentially reduces per capita healthcare expenditure by USD 22.7 and morbidity of environment-related diseases by 3.6 cases per 1000 population. In the education sector, the same increase potentially reduces the student-to-classroom ratio by 1.5 and increases the Education Infrastructure Index by 2.7 points. Larger increases in CE implementation (20% or 30%) show proportionally greater benefits. However, it should be noted that these linear projections may not fully reflect the actual complexity of the relationship, especially if there are threshold effects or non-linear relationships not captured in the estimation models.

DISCUSSION

This study provides robust empirical evidence for a causal relationship between Circular Economy implementation and improvements in health and education indicators across five ASEAN countries from 2015 to 2023. The regression results demonstrate that a 0.1-point increase in the Circular Economy Implementation Index (CEII) is associated with a significant reduction in per capita healthcare expenditure by USD 22.7 ($p < 0.001$), a decrease in the morbidity rate of environment-related diseases by 3.6 cases per 1,000 population ($p < 0.001$), and an increase in the Environmental Health Index (EHI) by 27.86 points ($p < 0.001$). Similarly, a 0.1-point CEII increase correlates with a 1.52-point reduction in the student-to-classroom ratio ($p < 0.001$), a 1.27% increase in education expenditure as a percentage of GDP ($p < 0.01$), and a 26.53-point improvement in the Education Infrastructure Index (EII) ($p < 0.001$). These findings align with Wang et al. (2021), who reported significant correlations between CE initiatives in Chinese cities and reduced respiratory and cardiovascular disease incidences ($r = -0.39$ and -0.27, $p < 0.05$). Likewise, Singh et al. (2024) found a 32% reduction in waterborne diseases in India due to CE-based waste management, supporting the observed health benefits in this study. However, unlike these studies, which focused on larger economies, this research highlights CE's impact in the Southeast Asian context, where quantitative analyses are scarce.

The mechanisms driving these relationships are multifaceted. First, the environment-health mechanism is evident in reduced pollution from circular economy practices like waste management and recycling. For instance, Thailand's Zero Waste programs, correlating with an 18% decrease in PM2.5 concentrations and a 22% reduction in respiratory disease hospitalizations (2018–2023), mirror findings by Yang et al. (2023), who noted the circular economy's role in mitigating air pollution. Similarly, Indonesia's plastic recycling initiatives reduced open waste burning by 35%, aligning with Jain and LaBeaud (2022), who linked plastic recycling to health gains. Second, the budget efficiency mechanism is supported by Malaysia's recycling program, which saved USD 60 million annually, partly redirected to build over 1.200 classrooms (2018–2023). This resonates with Kirchherr (2023), who found that a 10% reduction in waste production increased education expenditure by 1.2% of GDP, suggesting resource reallocation as a key pathway. Third, the capacity-building mechanism is reflected in Vietnam's integration of circular economy concepts into school curricula, correlating with improved PISA scores, consistent with Rabbi et al. (2024), who highlighted educational institutions as circular economy catalysts. Finally, the health-education mediation mechanism, where 35% of CEII's impact on EII is mediated through EHI, underscores a complex interplay, supporting Skene's (2022) conceptual framework linking the circular economy to health and education outcomes.

The heterogeneity analysis reveals higher elasticities in Vietnam and the Philippines, indicating greater marginal benefits in countries with lower initial CEII levels (0.43 and 0.41, respectively), compared to Malaysia and Thailand (0.69 and 0.72). This supports the "diminishing returns hypothesis," suggesting that less advanced CE systems yield larger relative gains, a pattern not extensively explored in prior Southeast Asian studies. These findings diverge from high-income country-focused research, emphasizing the unique potential of the circular economy in developing economies (Del Mar et al., 2021).

The implications are significant for Southeast Asian policy. CE should be viewed as a cross-sectoral strategy, not merely an environmental tool, as it yields dual benefits for health and education. Integrating circular economy into health and education policies can create synergies, aligning with Sustainable Development Goals (SDGs) for health (SDG 3) and education (SDG 4). Policymakers should prioritize CE interventions in countries like Vietnam and the Philippines to maximize impact, leveraging budget efficiencies and health improvements to enhance educational infrastructure. Future research should expand sample sizes and explore additional mediators to strengthen causal inferences, building on this study's foundation.

CONCLUSION

This research quantitatively examined the relationship between Circular Economy implementation and public health and education outcomes in five ASEAN countries (Indonesia, Malaysia, Thailand, Vietnam, and the Philippines) from 2015 to 2023. Results demonstrate that higher circular economy Implementation Index (CEII) scores are significantly associated with lower healthcare expenditure and reduced morbidity rates of environment-related diseases, alongside improvements in environmental health. Similarly, CEII correlates positively with educational outcomes, including higher primary school completion rates and improved education infrastructure. Path analysis reveals that 35% of the circular economy's impact on education infrastructure is mediated by better environmental health, confirming the interconnected nature of circular economy , health, and education.

These findings highlight that the circular economy should be viewed as a cross-sectoral development strategy offering dual benefits for health and education, beyond its environmental and economic roles. Integrating Circular Economy initiatives with health and education policies could enhance efficiency, support social equity, and accelerate progress toward multiple Sustainable Development Goals (SDGs). Policymakers are encouraged to design coordinated interventions that maximize resource use, strengthen human capital, and promote long-term sustainability.

Despite robust statistical analysis, this study's limited sample size (45 observations) restricts its generalizability. Potential endogeneity and unobserved variables may also limit strong causal inferences. Additionally, CEII serves as a composite indicator that may not fully capture contextual variations in Circular Economy practices. Future studies should expand the dataset to include more countries and longer timeframes, refine Circular Economy measurement tools, and explore additional mediating or moderating mechanisms. Employing experimental or quasi-experimental methods could strengthen causal evidence, enabling more precise policy guidance for sustainable regional development.

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