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The Grim Cost of Economic Growth and Environmental Degradation: A Comprehensive Panel ARDL Study of Public Debt in the ASEAN-5 Countries

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Abstract: This study uses panel ARDL analysis to investigate the connections between GDP growth, environmental degradation, and public debt in the ASEAN-5 countries (Malaysia, Thailand, the Philippines, Singapore, and Indonesia) from 1996 to 2021. It appears that economic development can increase public debt, but investment can reduce public debt in the long run. Moreover, there is a positive correlation between savings and public debt, but only in the short run. These findings raise important considerations for policymakers in striking a balance between economic development, environmental sustainability, and public debt. This study also suggests that savings may positively affect public debt in Indonesia. In contrast, investment may raise debt in the short term in Malaysia, the Philippines, and Singapore. The possible effects of corruption on public debt in the Philippines and environmental damage in both that country and Thailand are also highlighted. Keeping public debt at a manageable level requires policies that balance economic development and environmental protection, as emphasized by this research.

Keywords: economic growth; environmental degradation; investment; public debt; panel ARDL; ASEAN

Citation: Shaari, M.S.; Masnan, F.; Abd Rani, M.J.; Zainal Abidin, Z.; Ridzuan, A.R.; Othman, N. The Grim Cost of Economic Growth and Environmental Degradation: A Comprehensive Panel ARDL Study of Public Debt in the ASEAN-5 Countries. *Sustainability* **2023**, *15*, 10756. https://doi.org/10.3390/su151410756

Academic Editor: Alan Randall

Received: 10 May 2023
Revised: 30 June 2023
Accepted: 4 July 2023
Published: 8 July 2023

1. Introduction

According to Gaspar et al. [1], global public debt has increased significantly from 28% of GDP in 2008 to 256% in 2020, accounting for 40% of the total, the greatest percentage recorded since the middle of the 1960s. Since it poses a threat to the national economy, this rise in public debt has been a source of worry for nations all over the world [2–4]. Peng-Lee and Ng [5] contended that rising public debt may result in a significant financial burden for the government, harm economic activity, and obstruct a country's progress. Moreover, Jellies and Medas [6] argued that increases in debt may result in a slowdown in economic growth, which would lower consumption and public investment. The government's capacity to meet its citizens' demands and expand public services may be hampered as its debt burden increases dramatically. Moreover, Ouhibi et al. [7] claimed that increased public debt may decrease foreign direct investment (FDI), which would negatively affect liquidity, exports, inflation, unemployment, and economic growth.

Politicians and economists in the ASEAN region have been debating the issue of public debt, with opposing viewpoints offered by Hajian et al. [8]. Past studies on the factors that affect public debt have shown conflicting findings, particularly when it comes to the influence of economic growth [9]. According to certain studies, economic growth is essential for lowering national debt [10–12]. The justification for this is that as the economy expands, the government might be able to raise taxes and produce more money to pay down its debt. Moreover, stronger economic development might boost investor confidence, which would lower the government's borrowing cost and ultimately result in lower public debt. Yet, other research contends that increased economic development may increase governmental debt [13]. Government spending may increase to support the economy during periods of economic growth, which could result in a greater budget deficit and, ultimately, a rise in the national debt. Governments may also raise their debt levels to fund infrastructure and other investment initiatives to promote economic growth. The ASEAN-5 nations have put the ASEAN Economic Community (AEC) policy into practice to promote economic progress. This policy aims to promote greater regional trade in commodities, services, investments, and other areas. Due to the upward trend in economic growth in the ASEAN-5 nations, their public debt is at risk of rising.

2. An Overview of Public Debt, GDP, and CO2 Emissions in ASEAN-5 Countries

Figure 1 shows an increase in public debt in the ASEAN-5 nations from 1996 to 2021, with Singapore having the largest public debt as the sole advanced economy in the region. This implies that the government has borrowed large sums of money through various channels, including issuing Treasury securities, bonds, and loans. The Philippines, on the other hand, has seen a modest increase in public debt and currently has the lowest level among the ASEAN-5 nations.

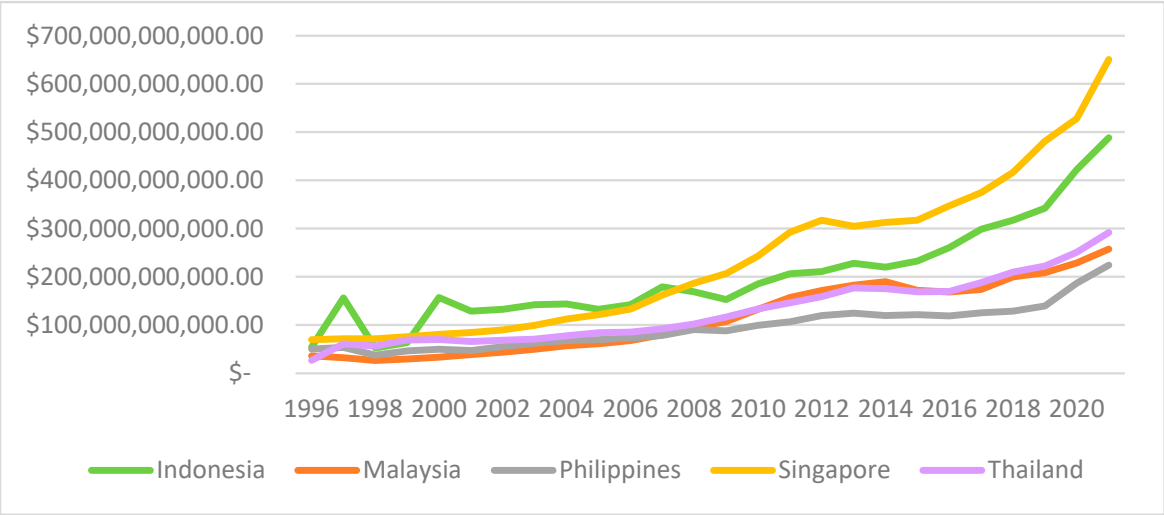

Figure 1. Public debt trends among ASEAN-5 countries. Source: countryeconomy.com.

Figure 2 depicts the ASEAN-5 nations' economic growth from 1996 through 2021, with a general upward trend. Particularly during the 1997–1998 economic crisis, these nations struggled to achieve economic development. The global financial crisis and the COVID-19 pandemic were blamed for the region's worrisome decrease in GDP and subsequent recessions in 2009 and 2020, respectively. In conclusion, many factors affect the direction of the complex relationship between public debt and economic development. To prevent a rise in public debt that could harm the economies of the ASEAN-5 nations, continuous attempts to spur economic growth must be closely monitored.

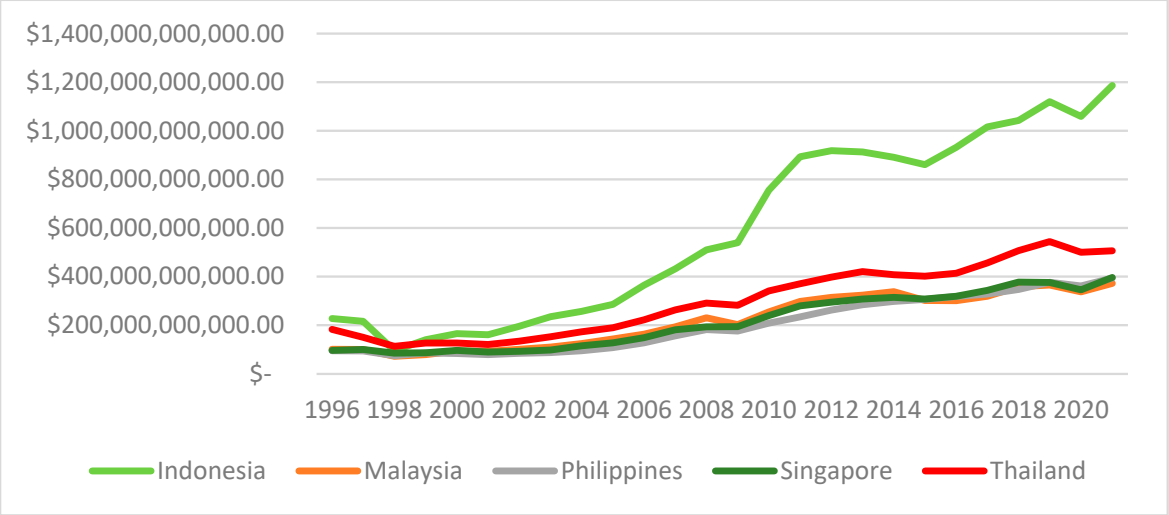

Figure 2. GDP in the ASEAN-5 countries (in billion US dollars). Source: countryeconomy.com.

According to Farooq et al. [14], there is a relationship between higher public debt and environmental degradation. However, it is important to note that environmental deterioration can also have an impact on public debt, in addition to its effects on economic growth. Despite this, past research did not take into account how the environment's decline affects public debt. By examining the connection between environmental damage and public debt, the new study seeks to close this gap. The International Energy Agency [15] reported a 3% increase to USD 30 billion in global spending on renewable energies to combat environmental degradation. But expensive environmental protection projects could cause a fiscal deficit, increasing the nation's debt. Moreover, health issues brought on by environmental deterioration might raise government health spending, which raises the national debt. By 2025, the ASEAN-5 nations hope to supply 23% of their energy needs from renewable sources, costing an additional USD 27 billion annually. Budget restrictions, however, have limited funding each year between 2016 and 2021 to no more than USD 8 billion. Also, the national budgets of the ASEAN-5 countries may increase as a result of tax incentives implemented by all of them to protect the environment.

The trend of carbon dioxide (CO2) emissions in the ASEAN-5 nations from 1996 to 2021 is depicted in Figure 3. The graph shows that all nations have struggled with rising CO2 emissions, with Indonesia having the largest emissions measured in metric tonnes because of its greater population. Singapore, in comparison, emits the least CO2 due to its lower population. Yet, albeit not significantly, the ASEAN-5 countries continued to see CO2 rise. According to the study's findings, the ASEAN-5 countries' efforts to address environmental degradation may result in higher national budgets and, as a result, higher public debt. Environmental degradation is a significant factor that affects public debt, and as a result, the ASEAN-5 countries' efforts to address this issue may have this effect. Hence, to ensure that economic growth is ecologically friendly and sustainable, policymakers should consider public debt.

This paper highlights the consequences of economic growth and environmental degradation on public debt in ASEAN5 countries. The theoretical background of the study is discussed in the following section, followed by a literature review in section three. The methodology used in this study is presented in section four, while the findings are presented in section five. Finally, the last section contains the conclusion and policy recommendations based on the study's results.

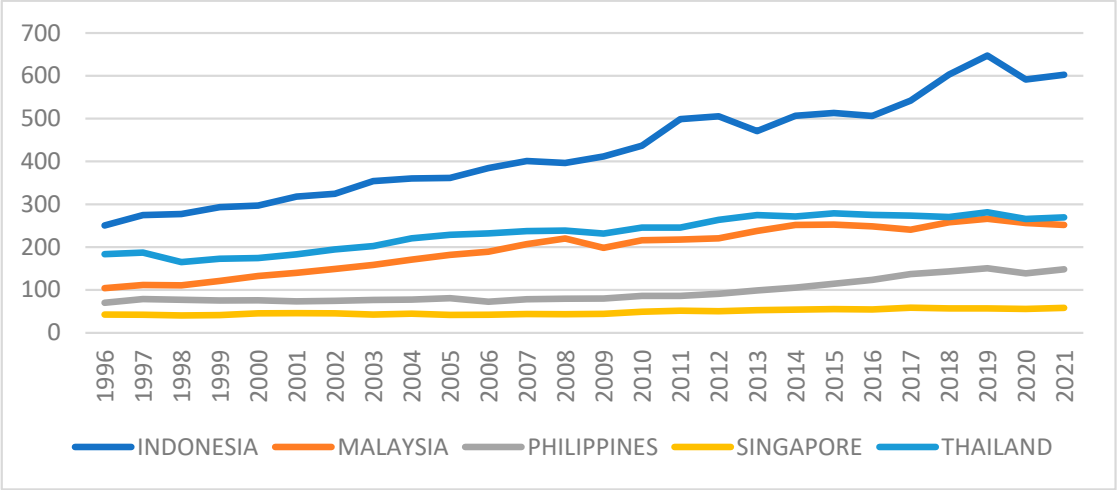

Figure 3. Carbon Dioxide (CO2) emissions in metric tons in the ASEAN-5 countries. Source: countryeconomy.com.

3. Theoretical Background

Public debt is a well-researched concept in the literature, generally defined as the cumulative amount of debt owed by the government and its affiliated entities [16]. Governments can incur public debt through various means, such as issuing securities, entering into debt agreements, and utilizing financial leases [17]. Peng-Lee and Ng [5] classify public debt into two categories: internal and external. The two-gap model, initially developed by Chenery and Strout [18], has been extensively utilized to examine the factors influencing public debt [19]. This model identifies two primary gaps, namely the savings–investment gap and the import–export gap, as key determinants of public debt [20,21]. Building upon the Harrod–Domar model, which highlights the interplay between savings, investment, and import capital [22], the two-gap model is particularly relevant for countries facing budget deficits due to low savings and investment [23]. Its simplicity has made it a useful tool employed by institutions like the Regional Development Bank and the International Monetary Fund (IMF) to assess appropriate debt levels for countries [24]. Recent studies, including Ekuoala [25], have frequently employed the two-gap model to investigate the factors driving public debt. By identifying the gaps between savings and investment and between imports and exports, this model provides a framework for analyzing the drivers of public debt. The theoretical literature offers insights into the relationship between public debt and investment, with a particular focus on the negative effects of public debt on investment. One relevant concept is the debt overhang theory, which suggests that high levels of public debt can have adverse consequences for investment. According to this theory, substantial debt burdens can create uncertainty and diminish investor confidence. The anticipation of future tax increases or reduced government spending to manage the debt may lead investors to perceive long-term investment projects as risky. Consequently, private investment levels may decline due to the prioritization of debt repayment over creating an environment conducive to investment.

Another theoretical perspective to consider is the crowding-out effect of government investment on private investment. This viewpoint posits that increased government investment may compete with the private sector for limited resources, such as capital and skilled labor. The resulting competition can drive up costs for private firms, restricting their ability to invest in productive endeavors. Consequently, government investment may crowd out private investment, leading to an overall decrease in investment levels. When analyzing the findings in relation to these theoretical perspectives, it is essential to consider that empirical results may not always align precisely with theoretical expectations. Country-specific characteristics, policy frameworks, and institutional arrangements can influence the relationship between public debt and investment. Therefore, while integrat-

ing the relevant theoretical frameworks into the analysis, it is crucial to acknowledge any deviations from existing theoretical perspectives and provide a nuanced understanding of the empirical findings within the specific context of the ASEAN-5 countries.

4. Literature Review

The previous research that has been conducted highlights the ways in which the impact of economic growth on different countries' levels of public debt. Scholars like Swamy [26], Waheed [12], Knapkova et al. [27], Sadik-Zada and Gatto [28], Briceo and Perote [29], Ridzuan et al. [30], Dawood et al. [9], and Ozturk et al. [31] used different methodologies to investigate the relationship between economic growth and public debt. However, they all came to the conclusion that economic growth has an effect on public debt in the majority of countries. For example, Ozturk et al. [31] carried out research in order to gain a better understanding of the factors that contributed to the debt crisis that began in 2009 in the European Union. The Vector Auto-Regressive (VAR) model was used in the research to analyze economic growth and inflation between 2000 and 2012. The researchers found that there is a negative connection between total public debt and economic growth. In addition, the research revealed a connection between price increases and the growing burden of public debt.

Waheed [12] conducted research to determine how eight different factors affect the amount of public debt in countries that both export and import petroleum products. The research looked at panel data from both nations that export oil and gas as well as countries that import oil and gas throughout a period of time spanning from 2004 to 2013. According to the findings, the general government budget, general government spending, inflation, and investment all have positive effects on public debt, but economic growth, the current account balance, oil prices, and foreign exchange reserves all have negative effects on public debt.

Several researchers, such as Asghar et al. [32], Dawood et al. [9], Hilton [33], Fatas et al. [34], and Gokmenoglu and Rafik [35], have investigated the effects that investment and economic growth have on the amount of public debt in a number of different nations. According to the findings of Dawood et al. [9], public debt can be reduced by investment. However, trade openness and government spending are positively related to public debt. In a study on the impacts of population, trade openness, inflation rate, and investment on public debt, Hilton [33] discovered that investment and trade openness consistently have a short-term negative relationship. Gokmenoglu and Rafik [35] came to the conclusion that there is a positive association between investment and public debt. Fatas et al. [34] concurred with this assessment and came to the same conclusion. According to the findings of Swamy [26], macroeconomic factors that have a negative impact on public debt include economic growth, foreign direct investment, government spending, inflation, and population, while factors that have a positive impact include final consumer spending and trade openness.

Knapkova et al. [27] found that a growing economy has a negative impact on public debt, while unemployment, trade openness, and the size of the public sector all have a positive impact on public debt. The study also discovered that economic contraction has a positive impact on public debt. Similarly, Briceo and Perote [29] investigated the factors that lead to governmental debt in the Eurozone by employing the Generalized Technique of Moments (GMM) approach. They found that ten variables that are associated with public debt had a negative connection with one another. Studies on China's national debt by Li and Li [36] and Dirir [13] examined the relationship between economic growth and public debt. They discovered that public debt increases with economic growth. This contradicts the findings of Sadik-Zada and Gatto [28].

The contradictory findings can be ascribed to a number of different causes. These factors include disparities in the time period studied. Swamy [26] looked at data from 252 different countries between the years 1980 and 2009, whereas Knapkova et al. [27] concentrated on the Slovak Republic between the years 1995 and 2017. Dirir [13] investigated the reasons for public debt in Djibouti and China, whereas Briceo and Perote [29]

investigated the causes of governmental debt in the Eurozone. In addition, numerous econometric approaches, such as the panel Granger causality, simple linear regression, GMM, and ARDL methods, were used in various research. There are some similarities across the studies, despite the fact that the procedures used to conduct the research were different. For instance, economic growth and government spending are two elements that are regularly investigated as potential influences on public debt. There was a correlation between economic growth and public debt, as discovered by Swamy [26], Knapkova et al. [27], and Dirir [13]. However, the direction of the correlation differed among the three studies. In the meantime, it was discovered by both Swamy [26] and Knapkova et al. [27] that the expenditure of the government has a negative effect on public debt.

With the exception of a select few studies like the one by Hajian et al. [8], the vast majority of previous research on the effects of economic growth and investment on public debt was carried out in nations that were not part of the ASEAN-5. For this reason, additional research on the countries that make up ASEAN-5 is required. In addition, despite the fact that a number of research studies have used panel and time-series data in order to investigate the causes of public debt, these studies have primarily focused on the effects of macroeconomic, socioeconomic, and governance issues; however, they have neglected to address the issue of environmental degradation, which could also help reduce public debt.

5. Methodology

This study explores whether economic growth and environmental degradation can contribute to public debt in the ASEAN-5 countries. The two-gap model suggests that public debt is influenced by gaps in savings and investment, as well as foreign exchange gaps measured by import and export gaps, commonly referred to as trade openness. However, this study applies the one-gap model consisting of savings and investment only. The decision to employ the one-gap model instead of the traditional two-gap model in this study is motivated by several factors specific to the context of the ASEAN-5 countries and the data availability. By opting for the one-gap model, the study aims to simplify the analysis and concentrate on the relationship between savings, investment, and public debt, facilitating a clearer examination of the factors that contribute to public debt within the ASEAN-5 countries. The two-gap model introduces complexity by incorporating both savings–investment gaps and foreign exchange gaps. While foreign exchange gaps are relevant to overall economic performance and balance of payments, their direct impact on public debt may differ. Public debt, on the other hand, is primarily influenced by factors associated with savings, investment, and economic growth. Therefore, excluding foreign exchange gaps from the model enables a more focused investigation of the factors directly linked to public debt in the ASEAN-5 countries. By utilizing the one-gap model and focusing on the specific factors of savings, investment, and economic growth, the study aims to provide valuable insights into the determinants of public debt in the ASEAN-5 countries while acknowledging that further research incorporating trade openness variables may be necessary to gain a more comprehensive understanding of the relationship between trade and public debt in this context. Therefore, we used several independent variables, including investment, gross domestic savings, gross domestic product (GDP), corruption, and CO2 emissions, with public debt serving as the dependent variable. The model specification employed to analyze the determinants of public debt in the ASEAN-5 countries is as follows:

$$LNPD_{it} = \beta_1 + \beta_{2i}\, LNINV_{it} + \beta_{3i}\, LNGDS_{it} + \beta_{4i}\, LNGDP_{it} + \beta_{5i}\, LNCOR_{it} + \beta_{6i}\, LNCO2_{it} + \varepsilon_{it} \quad (1)$$

In the model specification, LNPD denotes the natural logarithm of public debt, LNIV stands for the gross fixed capital formation representing investment, LNGDS represent the natural logarithm of gross domestic savings, LNGDP represents the natural logarithm of GDP at constant prices, LNCOR is the natural logarithm of corruption perceptions index,

and LNCO2 refers to the natural logarithm of CO2 emissions. The intercept is represented by β_1, while $_t$ denotes time, $_i$ denotes the cross-section, and ε represents the error term.

We utilized the ADF, IPS, and PP test statistics to determine the presence of a unit root in the data. These methods are well-suited for analyzing panel data due to their robustness [37,38] and ability to handle large datasets [39]. To examine the unit root, we employed a simple multiple-choice approach based on the *p*-values of individual unit root tests for each cross-section and panel [40]. The specific procedures for conducting the unit root test are outlined in Equation (2):

$$\Delta y_{it} = \theta_o + \theta y_{it-1} + \sum_{k=1}^{s_i} \alpha_i \Delta y_{it-1} + \delta' h_{it} + \mu_{it} \quad (2)$$

In Equation (2), it indicates the cross-section unit that investigates the times, and μ represents the residual procedure. The independent variables with fixed effects trends are denoted by h, and the autoregressive coefficients are denoted by s_i. The ADF and PP tests are derived from the formula and allow different lag orders to change across the section. Additionally, Equation (2) represents both the unit root and Fisher-PP tests for each cross section, which are critical in examining serial correlation.

We used the ARDL model to analyze our time series data to detect any long- and short-run equilibrium. The ARDL model effectively deals with two common challenges in panel data analysis: endogeneity and serial correlation. Endogeneity occurs when the independent variables are correlated with the error term, while serial correlation refers to the correlation between error terms across time. To tackle these issues, the ARDL model incorporates lagged dependent variables and error correction terms, effectively mitigating the problems associated with endogeneity and serial correlation. In this study, we utilized the ARDL model combined with the Pedroni cointegration test to examine the long- and short-run relationships among the variables of interest. The Pedroni cointegration test is a commonly used method for panel data analysis that allows us to determine whether a stable long-run equilibrium exists. The ARDL model, specified separately for the long run (Equation (3)) and the short run (Equation (4)), incorporates lagged differences of the variables as explanatory factors, along with an error term.

To determine the appropriate lag length for the ARDL model, we employed the Akaike Information Criterion (AIC). These criteria helped us select the optimal number of lags that capture the dynamics of the variables while avoiding overfitting. Cointegration analysis was conducted using the Pedroni test, which allowed us to assess the presence of a stable long-run relationship among the variables. The Pedroni test considers both the individual effects (within groups) and the common effects (across groups) in the panel data. If cointegration is confirmed, it suggests a long-run association among the variables. The panel ARDL analysis takes into account both the cross-sectional and time-series dimensions of the data, allowing for the estimation of both long- and short-term coefficients simultaneously while considering heterogeneity across the panel units. Estimation is typically carried out using panel data estimation techniques such as Pooled OLS, Fixed Effects, or Random Effects models. By employing the ARDL model with the Pedroni cointegration test and panel data techniques, we can comprehensively analyze the relationships among the variables of interest. This approach accounts for the dynamic nature of the data, considers potential long-run equilibrium, and accommodates variations across the panel units. These equations are presented below:

$$\begin{aligned}\Delta LNPD_{it} = \alpha_i + \sum_{i}^{p} \beta_{1ij} \Delta LNPD_{it-j} + \sum_{j}^{q} \beta_{2ij} \Delta LNINV_{it-j} + \sum_{k}^{r} \beta_{3ij} \Delta LNGDS_{it-j} + \sum_{l}^{s} \beta_{4ij} \Delta LNGDP_{it-j} \\ + \sum_{m}^{t} \beta_{5ij} \Delta LNCOR_{it-j} + \sum_{n}^{u} \beta_{6ij} \Delta LNCO2_{it-j} + \varepsilon_{it}\end{aligned} \quad (3)$$

i, t, and j indicate the cross-sectional unit, time period, and optimal lags, respectively, according to Equation (3). p, q, r, s, t, and u reflect the optimal lag order, whereas the error term is denoted by ECT. As proposed by Pesaran and Smith [41], it is necessary to

verify the stationarity of all variables before using the panel ARDL method. This includes guaranteeing that the dependent variable is stationary at the first difference, and that all independent variables are stationary at either the level or the first difference, i.e., I(0) or I(1). To assess if cointegration exists, we reject the null hypothesis if the calculated F statistic exceeds I(1), accept it if it falls below I(0), and remain inconclusive if it falls between I(0) and I(1). In addition, if the F-statistic surpasses the upper critical value, the results support the conclusions of Shahbaz et al. (2014) [42] and the long-run association. Finally, Equation (4) shows the estimation of the short-run model for the variables:

$$\Delta LNPD_{it} = \pi_i + \sum_{i}^{p} \sigma_{1ij} \Delta LNPD_{it-j} + \sum_{j}^{q} \sigma_{2ij} \Delta LNINV_{it-j} + \sum_{k}^{r} \sigma_{3ij} \Delta LNGDS_{it-j} + \sum_{l}^{s} \sigma_{4ij} \Delta LNGDP_{it-j} + \sum_{m}^{t} \sigma_{5ij} \Delta LNCOR_{it-j} + \sum_{n}^{u} \sigma_{6ij} \Delta LNCO2_{it-j} + \phi_{ij} ECT_{t-i} + \mu_{it} \quad (4)$$

According to Equation (4), when short-term disturbances occur, the Error Correction Term (ECT) plays a crucial role in determining the speed at which the long-term equilibrium is reached by examining the relationship between the variables under consideration. The value of ECT_{t-i} indicates the extent to which the model converges toward the long-term equilibrium after a shock and is represented by the parameter ϕij. It is important to note that the coefficients of ECT_{t-i} need to be both negative and statistically significant.

6. Findings

The stationarity of the time series data was examined by conducting unit root tests using the LLC, IPS, and ADF methods. Time series data must exhibit stationarity in order to be useful for data modeling. Stationarity refers to the statistical features of the data, such as the mean and variance, being constant across time. The results of the LLC, IPS, and ADF tests reported in Table 1 show that all variables are stationary at the first difference. Stationarity is most evident in the first difference of each variable. These results are favorable as the panel ARDL can be employed, a widely used econometric technique that estimates the long-run relationship between investment, savings, economic growth, corruption, environmental degradation, and public debt.

Table 1. Unit Root Results.

Variables	LLC		IPS		ADF	
	Level	1st Difference	Level	1st Difference	Level	1st Difference
LNCO2	−1.499 (0.067)	9.307 (0.000)	0.355 (0.639)	−8.777 (0.000)	8.344 (0.595)	77.641 (0.000)
LNCOR	0.060 (0.524)	−8.813 (0.000)	0.008 (0.503)	−9.974 (0.000)	9.676 (0.469)	89.173 (0.000)
LNGDP	−0.093 (0.463)	−9.091 (0.000)	2.991 (0.999)	−7.832 (0.000)	1.392 (0.999)	68.555 (0.000)
LNGDS	0.676 (0.751)	−7.890 (0.000)	2.515 (0.994)	−7.057 (0.000)	1.608 (0.999)	60.889 (0.000)
LNINV	−4.072 (0.000)	−6.352 (0.000)	−4.035 (0.000)	−5.442 (0.000)	36.325 (0.000)	46.179 (0.000)
LNPD	1.230 (0.891)	−13.391 (0.000)	3.155 (0.999)	−12.952 (0.000)	3.236 (0.975)	84.369 (0.000)

Next, we conducted panel cointegration tests within and between dimensions to analyze the impacts of investment, savings, economic growth, and environmental degradation on public debt. The findings presented in Table 2 reveal that among the seven statistics used, only the panel PP-Statistic, panel ADF-statistic, and Group PP-Statistic are significant. The significance of these statistics implies that a long-term relationship exists between the aforementioned independent variables and public debt. Therefore, the panel ARDL approach can be employed to estimate this long-term relationship. Panel ARDL models can

accommodate both cross-sectional and time-series dimensions, enhancing the estimation's accuracy. Furthermore, the results suggest that investment, savings, economic growth, and environmental degradation can substantially influence public debt.

Table 2. Cointegration Results.

	within Dimension	
	without Trend	**with Trend**
Panel v-Statistic	1.025 (0.153)	0.898 (0.185)
Panel rho-Statistic	−0.771 (0.220)	−0.112 (0.455)
Panel PP-Statistic	−3.875 (0.000)	−4.684 (0.000)
Panel ADF-Statistic	−4.556 (0.000)	−4.596 (0.000)
	between Dimension	
	without Trend	**with Trend**
Group rho-Statistic	0.920 (0.821)	1.465 (0.929)
Group PP-Statistic	−1.820 (0.034)	−2.333 (0.010)
Group ADF-Statistic	−1.190 (0.117)	−1.466 (0.071)

Based on Table 3, savings are significant at the 5% level in the short run with a coefficient of 0.26, indicating that changes in savings have a statistically significant impact on public debt in the short term. However, savings are not statistically significant in the long run, with a coefficient of 0.102, suggesting that savings may not significantly impact public debt in the long term. The positive coefficient of savings in both the short and long run implies that an increase in savings leads to a rise in public debt. Although this outcome may appear contradictory, rising savings may likely result in falling expenditure, slowing economic development. This could thus make it more necessary for the government to borrow money to finance public spending, pushing up public debt. Contrary to the findings of Nagou et al. [20] and Shah et al. [21], it is important to note that an increase in savings can potentially lead to a decrease in expenditure, which in turn may hinder economic development. While they might suggest a positive relationship between savings and economic growth, it is crucial to consider the possibility that higher savings rates could lead to reduced spending, potentially slowing down overall economic progress. This could thus make it more necessary for the government to borrow money to finance public spending, pushing up public debt.

Table 3. Long-run and Short-run Effects Results.

Long Run				**Short Run**		
Variables	**Coefficient**	**t-Statistic**	**Prob.**	**Coefficient**	**t-Statistic**	**Prob.**
LNGDS	0.102	0.393	0.695	0.260	2.008	0.048
LNINV	−1.156	−5.302	0.000	0.127	0.459	0.647
LNGDP	1.780	10.573	0.000	−1.114	−1.028	0.307
LNCOR	0.027	0.114	0.909	0.001	0.027	0.979
LNCO2	−0.059	−0.169	0.866	0.912	1.410	0.162
ECT	−	−		−0.500	−2.534	0.013

Moreover, investment is statistically significant at the 1% level in the long run, with a coefficient of −1.156, indicating that changes in investment have a statistically significant

impact on public debt in the long term. However, in the short run, investment is not statistically significant, with a coefficient of 0.126, suggesting that investment may not significantly impact public debt in the short term. In the long run, the negative coefficient of investment indicates that an increase in investment leads to a decrease in public debt. This result implies that investment can be a powerful tool for managing public debt in the long run. The finding of this study is consistent with the research conducted by Dawood et al. [9] and Hilton [33]. However, it is important to note that Dawood et al. [9] employed a different method, namely GMM, in their study, which focused on 32 Asian developing and transitioning economies. In contrast, Hilton [33] utilized the ARDL approach but focused on a single country, Ghana. These studies provide additional support to the current research by examining public debt and its determinants in different contexts and using alternative methodologies.

Economic growth is statistically significant at the 1% level in the long run, with a coefficient of 1.78, indicating that changes in economic growth have a statistically significant impact on public debt in the long term. However, in the short run, economic growth is not statistically significant, with a coefficient of −1.114, suggesting that economic growth may not significantly impact public debt in the short term. In the long run, the positive coefficient of economic growth indicates that an increase in economic growth leads to an increase in public debt. An increase in economic growth leads to an increase in public expenditure, which can cause an increase in public debt. This finding is consistent with the research conducted by Ozturk et al. [31], although there are some differences in their approach. Ozturk et al. [31] employed the VAR approach to analyze data from the European Union. Despite the methodological differences, their study also supports the notion that economic growth positively affects public expenditure and subsequently public debt.

Based on the findings, corruption is statistically insignificant at any level in both the short and long run. This indicates that changes in corruption levels do not significantly impact public debt in the short or long term. This result may seem surprising as corruption has been widely reported to affect economic growth and public finances negatively. However, other factors such as investment, savings, economic growth, or environmental degradation may significantly impact public debt, thus overshadowing the effect of corruption. Another possible explanation for the lack of significance of corruption is that the measures used to quantify corruption may not fully capture its true extent or impact. Corruption is often difficult to measure, and different measures may yield different results. According to our findings, the coefficient of environmental degradation is statistically insignificant at any level in both the short and long run. This suggests that changes in environmental degradation levels do not have a statistically significant impact on public debt in either the short or long term.

The results also show that the coefficient of the ECT is −0.500 and significant. The negative sign of the ECT coefficient suggests that any deviation from the equilibrium is corrected at 50% per period. If a short-term disturbance, such as a sudden increase in public debt, the system will adjust toward its long-run equilibrium, which may involve reducing public debt levels. The significance of the ECT coefficient at the 5% level suggests that the model is reliable and accurately captures the relationship between environmental degradation and public debt.

The results of the individual short-run effects reported in Table 4 suggest that investment may increase public debt in Malaysia, the Philippines, and Singapore. Investment is often viewed as a driver of economic growth and potential government revenue. However, an excessive investment may lead to a surge in public spending, causing an increase in public debt. As such, policymakers must be cautious when pursuing investment-driven growth strategies and balance them with measures to reduce public debt. The study also suggests that savings can increase public debt in Indonesia. While savings can be an important tool for economic stability, if not accompanied by investment, it may lead to reduced economic growth and increased public debt. In this case, policymakers may need to encourage investment to balance out the effects of savings. Interestingly, the study

suggests that corruption may reduce public debt in the Philippines. This finding may be due to corrupt officials siphoning off government resources, leading to decreased public spending and a corresponding reduction in public debt. However, it is important to note that this reduction in public debt may come at a high cost to the economy's overall health. Furthermore, the study suggests environmental degradation can increase public debt in the Philippines and Thailand. This may be due to the costs associated with environmental damage, such as clean-up and rehabilitation efforts. In this case, policymakers may need to consider implementing measures to mitigate environmental damage, which may also help reduce public debt.

Table 4. Individual Short-run Effects Results.

Countries	Variables	ECT	LNGDS	LNINV	LNGDP	LNCOR	LNCOR
Malaysia	Coeff.	−0.203	−0.080	0.453	−0.299	−0.033	0.360
	Std. Error	0.003	0.093	0.039	0.456	0.065	0.180
	Prob.	0.000	0.453	0.001	0.559	0.649	0.140
Indonesia	Coeff.	−1.179	0.614	0.719	0.131	−0.050	0.089
	Std. Error	0.052	0.109	0.767	2.383	0.152	0.398
	Prob.	0.000	0.011	0.418	0.960	0.764	0.837
Philippines	Coeff.	−0.272	0.221	−0.901	−0.139	−0.113	0.496
	Std. Error	0.015	0.098	0.186	1.668	0.021	0.175
	Prob.	0.000	0.110	0.017	0.939	0.012	0.066
Singapore	Coeff.	−0.136	0.058	0.219	0.172	0.089	0.134
	Std. Error	0.003	0.081	0.026	0.131	0.232	0.063
	Prob.	0.000	0.527	0.004	0.280	0.728	0.122
Thailand	Coeff.	−0.711	0.489	0.144	−5.435	0.113	3.483
	Std. Error	0.036	0.740	0.174	3.800	0.114	1.163
	Prob.	0.000	0.556	0.469	0.248	0.393	0.058

We performed the FMOLS and DOLS tests to assess the robustness of our findings obtained from the ARDL estimation. These tests serve as additional analyses to strengthen the validity of our results. The FMOLS and DOLS estimations reveal important insights into the relationship between the variables and public debt. Specifically, our findings indicate that gross domestic investment, GDP, and corruption significantly impact public debt. Higher levels of investment and GDP are associated with an increase in public debt, while elevated levels of corruption are also linked to higher public debt. The results from both the FMOLS and DOLS estimations provide evidence of the statistically significant effects of gross domestic investment, GDP, and corruption on public debt. The findings suggest that higher levels of investment and GDP contribute to an increase in public debt, while elevated corruption levels are also associated with higher public debt. In contrast, the variables related to gross domestic savings (LNGDS) and CO2 emissions (LNCO2) do not demonstrate a significant impact on public debt in this analysis (Table 5).

Table 5. FMOLS and DOLS Results.

	FMOLS			DOLS		
Variable	**Coefficient**	**t-Statistic**	**Prob.**	**Coefficient**	**t-Statistic**	**Prob.**
LNGDS	0.139	0.738	0.462	−0.260	−1.269	0.213
LNINV	−1.084	−4.006	0.000	−1.452	−5.513	0.000
LNGDP	0.868	4.957	0.000	1.265	6.485	0.000
LNCOR	0.812	5.188	0.000	0.895	4.365	0.000
LNCO2	−0.149	−1.222	0.224	0.166	1.376	0.178

7. Conclusions and Policy Recommendations

This study investigates the relationship between economic growth, environmental degradation, and public debt in the ASEAN-5 countries, including Malaysia, Thailand, the Philippines, Singapore, and Indonesia, using panel ARDL analysis based on data spanning from 1996 to 2021. The findings suggest that investment can reduce public debt in the long run, whereas economic growth has the opposite effect. However, in the short run, only savings appear to have a positive relationship with public debt. These results have important implications for policymakers and stakeholders in the region who seek to balance economic growth with sustainable environmental practices while maintaining a manageable level of public debt. Based on the findings of this study, it appears that investment could potentially increase public debt in Malaysia, the Philippines, and Singapore in the short run. Furthermore, the results indicate that savings may have a positive relationship with public debt in Indonesia over the same time frame. It is also noteworthy that the study suggests that corruption might be associated with a reduction in public debt in the Philippines. Finally, the study provides evidence that environmental degradation could increase public debt in both the Philippines and Thailand.

The findings of our study have important policy implications for addressing public debt dynamics, economic growth, and environmental degradation in the ASEAN-5 countries. Policymakers can use these results to formulate effective strategies and policies promoting sustainable economic development while ensuring fiscal responsibility. Firstly, policymakers need to balance economic growth with fiscal responsibility. Given that economic growth can increase public debt, it is crucial to adopt measures that prioritize public investment projects with positive impacts on economic growth while minimizing the burden on public debt. This may involve rigorous project evaluation and selection processes to identify high-impact investments that align with long-term growth objectives. To ensure fiscal sustainability, policymakers should consider implementing fiscal rules or limits on public debt. This could involve setting targets for debt-to-GDP ratios or adopting balanced budget requirements. These measures can help maintain a stable fiscal environment and prevent excessive public debt accumulation, ensuring long-term economic sustainability and stability. Regarding environmental degradation, policymakers need to address the environmental impact of economic activities. Promoting sustainable development practices is crucial for reducing the adverse effects of environmental degradation on public debt. Policymakers should prioritize investments in renewable energy, green infrastructure, and sustainable agricultural practices. These investments not only contribute to environmental sustainability but also have the potential to foster economic growth and job creation.

Governments can also impose a higher tax on firms with significant CO2 emissions to serve as a financial disincentive for such companies to continue polluting the environment. This tax policy aims to internalize the external costs associated with carbon emissions, incentivizing firms to adopt cleaner and more sustainable practices. The government can generate additional revenue by implementing a higher tax on CO2-emitting firms. This increased revenue can then be utilized to reduce the public debt burden. The additional funds collected from the tax can be allocated to debt repayment or used to finance government expenditure, thereby reducing the need for borrowing and contributing to a decline in public debt levels. Moreover, implementing a higher tax on firms with high CO2 emissions aligns with the principle of polluter pays, where those who contribute the most to environmental degradation bear a larger financial responsibility. This approach not only addresses the issue of public debt but also promotes environmental sustainability by discouraging harmful practices and encouraging investment in cleaner technologies and processes. Lastly, international cooperation and collaboration are crucial in addressing environmental challenges. Policymakers should actively engage in regional and global forums to exchange knowledge, share best practices, and coordinate efforts in addressing cross-border environmental issues. Collaborative approaches are necessary to manage environmental degradation and its implications for public debt effectively.

In summary, our empirical findings and theoretical insights provide policymakers in the ASEAN-5 countries with valuable guidance for addressing public debt dynamics, economic growth, and environmental degradation. Policymakers should prioritize sustainable economic development, consider fiscal responsibility measures, promote environmentally friendly practices, increase public awareness, and foster international cooperation. By implementing these recommendations, policymakers can work toward achieving a balance between economic growth, fiscal stability, and environmental sustainability.

One limitation of the study is that it uses the one-gap model instead of the traditional two-gap model, excluding the foreign exchange gaps related to trade openness. This omission may overlook the potential influence of trade imbalances on public debt dynamics in the ASEAN-5 countries. In addition to examining trade openness, it is also crucial to evaluate the impact of foreign direct investment (FDI) on the level of public debt. To address this limitation, future research should incorporate trade openness variables better to understand the relationship between trade imbalances and public debt. Understanding the relationship between FDI and public debt is essential for comprehensively assessing the economic dynamics and potential risks associated with FDI inflows. Additionally, investigating other factors such as fiscal policies, government expenditure, and environmental regulations can enhance understanding of their interactions with economic growth and public debt. Employing advanced econometric techniques and expanding the analysis to include a larger sample of countries or regions would also contribute to a more robust assessment of the relationship. By addressing these recommendations, future research can provide valuable insights for policy frameworks and sustainable economic management strategies.

Author Contributions: The manuscript was collaboratively written and revised by a team of authors, namely M.S.S., A.R.R., F.M. and M.J.A.R. The central idea of the research was developed by M.S.S., Z.Z.A., N.O. and F.M. while the initial manuscript was reviewed by A.R.R., M.J.A.R. and F.M. Additionally, A.R.R. verified the analytical method and interpretation of the results presented in this article. The revised version of the manuscript was supervised by M.S.S. and A.R.R. as the corresponding authors. All authors have read and agreed to the published version of the manuscript.

Funding: This research paper is funded by Young Talent Researcher Grant -600-RMC/YTR/5/3 (003/2022), provided by Universiti Teknologi MARA, Malaysia, and Geran Penyelidikan Dalaman KUPTM (UGP) Sesi 2/2022 (KUPTM DVCRI.RMC.15(47)) by Kolej Universiti Poly-Tech MARA Kuala Lumpur, Malaysia.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are available from World Bank Development Indicator.

Conflicts of Interest: All authors declare no conflict of interest.

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