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Article

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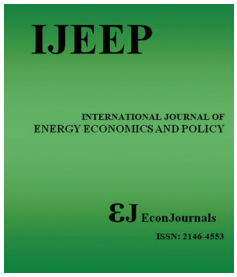

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How do Environmental Quality and Technology Affect Public Debt in Indonesia? A Time Series Analysis

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ABSTRACT

In recent years, Indonesia has grappled with a notable surge in public debt, underscoring the urgency of prudent fiscal management. This study employs the Autoregressive Distributed Lag (ARDL) method to investigate the long-term connections between key variables, including gross domestic product, gross domestic investment, gross domestic savings, carbon emissions, and technology, using data from 1990 to 2020. Our findings reveal a significant and negative association between savings and environmental degradation with Indonesia's public debt. These insights bear substantial policy implications, emphasizing the importance of integrating environmental considerations into economic planning and suggesting that the banking sector could enhance fiscal stability by incentivizing increased savings rates. This study provides valuable guidance for policymakers and economists seeking to foster Indonesia's economic resilience in the face of mounting public debt.

Keywords: Environmental Quality, Public Debt, Time Series, Macroeconomic
JEL Classifications: E00; Q56; O32

1. INTRODUCTION

Indonesia as the largest nation made up of islands in the world, is frequently praised for its rich cultural diversity, abundant of natural resources and consistent economic progress. Nevertheless, the increasing public debt of this dynamic country is a difficult and urgent matter, though. Concerns regarding Indonesia's long-term fiscal stability and economic resilience have been raised in recent years as a result of the country's alarming rapid public debt growth since 2012. It can be shown in Figure 1 as illustrated below.

By referring to Figure 1, the highest debt to GDP ratio for Indonesia was recorded in the year of 1997, with 72.48%. It was due to the Asian Financial Crisis that hit the Southeast Asian countries, including Indonesia (Kim, 2022). By comparing this percentage with the recent record in 2020, there was a sharp decline from 72.48% to 42.91%. Although the fact that the recent percentage may seem modest, it has significantly increased from prior years. The increase in Indonesia's public debt is the result of numerous reasons. Among others are the initiatives to improve technological growth, lack of domestic savings as well as the issue of climate change.

By looking at Figure 2, the number of patents applications have increased drastically in Indonesia from 1990 to 2020. Indirectly, it implies that the technological growth and development is increasing

progressively, consistent with Indonesia's aspiration to become a developed nation by 2045 (Maryanti et al., 2023). For sure, such technological growth and development requires massive amount of funds for the government to promote invention and innovation among its population. It might affect the level of public debt in general.

Besides, the issue of environmental degradation due to the increase in the carbon dioxide (CO_2) emission is also critical for Indonesia's economy. Global warming has precipitated significant challenges, including flooding, the elevation of sea levels, wildfires, air pollution, and numerous other consequences. Some of these disasters have incurred substantial financial losses for governments Pujiati et al. (2023); and Shaari et al. (2022)]. The green initiatives conducted by the Indonesian government aim to reduce carbon emission by investing more funds in renewable energy and reforestation, Voumik et al. (2023). This, for sure, will increase the government's fiscal burden (Farooq et al., 2023) and have a tendency to grow the debt level.

As public debt grows, so do its servicing expenses. The government is required to set aside a sizeable amount of its budget for interest payment, which takes money away from expenditures in infrastructure, healthcare, and other vital public services. Besides, high amounts of public debt can make the economy more susceptible to outside shocks and interest rate changes. It is then has the potential to erode investor's confidence, obstruct capital flows and impede economic expansion. According to Crude Keynesianism, public debt can lead budget deficit that weights the government, which then increases taxes (Phelps, 2022)

Indonesia must act decisively to address its public debt issue in order to preserve its fiscal stability and foster sustainable economic growth. According to Ali and Mustafa (2012), debt count have a positive impact on economic growth through the inflow on foreign capital, which lead to industrial development and technology expansion. Thus, investigating the factors that influence Indonesia's public debt is crucial for encouraging responsible fiscal management, maintaining sustainable economic growth and formulating effective policy. Indonesia can steer its economy towards fiscal stability while successfully tackling the issues caused by climate change, less domestic savings as well as the needs for technological development. These are among the three main variables that will be used in this study, apart from the macroeconomic indicators.

This study has a notable gap in research. Even though patents' applications are important indications of technological development, previous research has paid less attention to their potential impact on the budgetary health of a nation. Thus, it leaves a substantial knowledge gap to be investigated.

2. LITERATURE REVIEW

Public debt dynamics are of paramount interest to economists and policymakers on a global scale, as the effective management of public debt is crucial for ensuring fiscal sustainability and economic stability. This literature review synthesizes findings from a collection of studies that investigate the impact of macroeconomic indicators on public debt across various countries. The insights gained from these studies provide valuable guidance for policymakers and economists working towards a comprehensive understanding of public debt and its management.

The first set of studies, centered on specific countries, offers valuable insights into the relationship between macroeconomic indicators and public debt. Knapkova et al. (2019) explored the case of Slovakia, identifying GDP growth and government bond yields as positive influencers of public debt, while unemployment rates, economic openness, and public sector size exerted negative influences. In Tunisia, Samia and Hanen (2017) highlighted the significance of inflation and investment as debt reducers and emphasized the importance of fiscal adjustments and enhancing the productive capacity of the economy. John et al. (2022) investigated various macroeconomic determinants, including foreign direct investments (FDI) inflow, gross capital formation, inflation rate, and trade balance, and found FDI to have a significant negative impact on public debt, implying its potential as a debt reduction measure.

The second set of studies takes a broader view, examining macroeconomic determinants of public debt across countries. Ngasamiaku et al. (2022) employed the ARDL model to study Tanzania, identifying co-integration among determinants. They found imports and government spending to positively affect public debt, while inflation rate had a negative impact. The role of foreign

Figure 1: Trend of Indonesia's debt to GDP ratio from 1990 to 2020

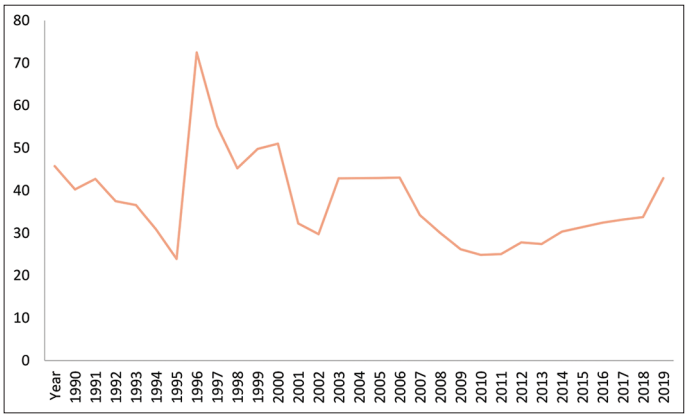
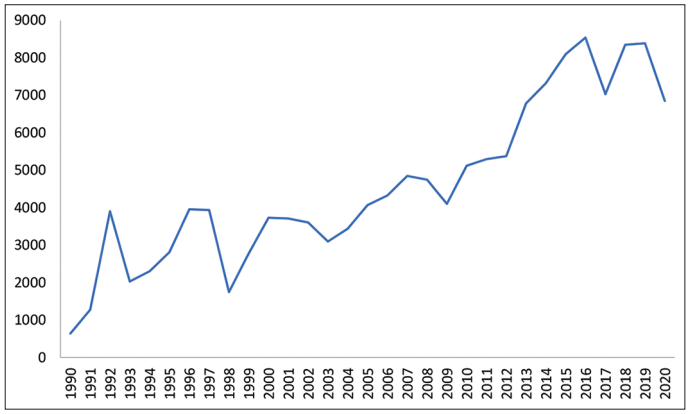


Figure 2: Ratio of total patent applications per Indonesia's population from 1990 to 2020



direct investment was statistically insignificant. In Kenya, Kirui (2017) emphasized that all identified variables, except for the real interest rate, significantly influenced public debt variations. This suggests the necessity of exploring both monetary and fiscal policy tools to manage debt accumulation effectively.

The final set of studies delves into unique aspects of public debt dynamics. Shaari et al. (2023) examined the connections between GDP growth, environmental degradation, and public debt in ASEAN-5 countries. The authors used panel ARDL and the sample data was taken from 1996 till 2021. They found that economic development could increase public debt, while investment could reduce it in the long run. The study underscored the importance of balancing economic development, environmental sustainability, and public debt management.

The comprehensive findings from these studies illuminate the intricate relationship between macroeconomic indicators and public debt accumulation in various contexts. Policymakers and economists can draw upon these insights to inform effective decision-making and strategies for managing public debt. The importance of sound fiscal policies, productive investments, and political and institutional stability in achieving fiscal sustainability and economic growth is underscored. It is also noted that not so much previous studies have been conducted on testing the impact of environmental degradations towards public debt. As the complexities of public debt persist, further research in this domain remains essential for advancing our understanding and refining management strategies.

3. METHODOLOGY

3.1. Data

This study centers on the analysis of factors contributing to public debt in Indonesia. It specifically investigates the potential impacts of economic growth, domestic investment, domestic saving, environmental quality, and technology. The sources of data are displayed in Table 1. To accomplish this goal, we analyze data spanning from 1990 to 2020 and employ various statistical tests to ensure data accuracy. The research utilizes the ARDL (Autoregressive Distributed Lag) methodology for cointegration, as initially proposed by Pesaran et al. (2001).

3.2. Theoretical Framework and ARDL Model

The model of public debt for Indonesia is proposed as follows:

$$PD_t = f(GDP_t, GDI, GDS_t, CO2_t, TEC_t) \quad (1)$$

where
GDP_t represents economic growth
GDI_t represent domestic investment
GDS_t represents saving
CO_2t represents environmental quality
TEC_t represents technology

Economic growth may have an ambiguous relationship with public debt, as it can increase debt when government spending surges during expansions (positive), but it may reduce debt if investments in growth-inducing areas like infrastructure are prioritized (negative). High domestic investment is expected to have a negative relationship with public debt, stimulating economic activity and increasing tax revenue. Conversely, low domestic saving rates may lead to more external borrowing and higher public debt (positive). Environmental quality, when good, can reduce public debt due to economic benefits like tourism and improved health outcomes (negative), while poor environmental quality may lead to increased government spending and higher debt (positive). A higher level of technology is anticipated to reduce public debt (negative) by boosting productivity and tax revenue, although large technology investments funded by borrowing could increase it (positive). These relationships depend on how factors are managed and their impact on government finances and economic growth.

To calculate both short-run and long-run elasticities, we have applied a log-linear transformation to the variables in Equation 1. This transformation is well-known for its ability to produce reliable and consistent estimations. Consequently, we present the logarithmic rendition of Equation 1 as follows:

$$LNPD_t = \delta_0 + \alpha_1 LNGDP_t + \beta_2 LNGDI_t + \sigma_3 LNGDS_t + \phi_4 LNCO_{2t} + \lambda_5 LNTEC_t + \mu_t \quad (2)$$

The subsequent expression represents the ARDL model, incorporating the Unrestricted Error Correction Model (UECM):

$$\begin{aligned}\Delta LNPD_t &= \beta_0 + \theta_0 LNPD_{t-1} + \theta_1 LNGDP_{t-1} + \theta_2 LNGDI_{t-1} \\ &+ \theta_3 LNGDS_{t-1} + \theta_4 LNCO2_{t-1} + \theta_5 LNTEC_{t-1} \\ &+ \sum_{i=1}^{a} \beta_i \Delta LNPD_{t-i} + \sum_{i=0}^{b} \gamma_i \Delta LNGDP_{t-i} \\ &+ \sum_{i=0}^{c} \delta_i \Delta LNGDI_{t-i} + \sum_{i=0}^{d} \lambda_i \Delta LNGDS_{t-i} \\ &+ \sum_{i=0}^{e} \vartheta_i \Delta LNCO2_{t-i} + \sum_{i=0}^{f} \psi_i \Delta LNTEC_{t-i} + \upsilon_t \end{aligned} \quad (3)$$

Equation 3 employs the first difference operator (Δ) to capture short-term effects, where "ut" signifies the white-noise disturbance term. To establish the validity of the UECM model, it is crucial to ensure that its residuals do not exhibit serial correlation and that the model remains stable. Validation of these assumptions is conducted through diagnostic tests, as detailed in the analysis section.

The final rendition of the model, as presented in Equation 3, can also be interpreted as an autoregressive distributed lag (ARDL) model with a specific order denoted as (a b c d e f). This model indicates that public debt (LNPD) is influenced not only by its past values but also by other external disturbances or shocks.

To calculate the long-term elasticity, you can divide the coefficient of the lagged explanatory variable (multiplied by a negative sign) by the coefficient of the lagged dependent variable. On the contrary, the short-term effects are captured by the coefficients of the first-differenced variables.

The null hypothesis for no co-integration in the long-term relationship is expressed as follows:

H_0: $\theta_0=\theta_1=\theta_2=\theta_3=\theta_4=\theta_5=0$ (there is no long-run relationship), is tested against the alternative of H_1: $\theta_0\neq\theta_1\neq\theta_2\neq\theta_3\neq\theta_4\neq\theta_5\neq0$ (there is a long-run relationship exists).

The F-test is a commonly used method for evaluating the existence of co-integration in the long-term relationship. When the calculated F-statistic falls below the lower critical value, it is not feasible to reject the null hypothesis of no co-integration. Conversely, if the computed F-statistic exceeds the upper critical value, with a significance level of at least 10%, the null hypothesis of no co-integration is rejected.

4. EMPIRICAL RESULTS AND DISCUSSION

The analysis of ARDL begins by examining the stationarity of unit roots for each variable, as suggested in this study. Two commonly employed unit root tests, namely the Augmented Dickey-Fuller (ADF) and Philip Perron Unit Root tests, are utilized for this purpose. Referring to Table 2, the results reveal mixed evidence of stationarity for both tests, indicating the appropriateness of ARDL estimation as a means to assess the model's long-term and short-term elasticities.

Table 1: Variables description

Variable	Symbol	Definition
Public Debt	PD	General government gross debt (current US$)/Indonesia Debt to GDP Ratio
Gross Domestic Product	GDP	GDP per capita (constant 2015 US$)
Gross Domestic Investment	DI	Gross fixed capital formation (% of GDP)
Gross Domestic Savings	GDS	Gross Domestic Savings (Current US$)
Carbon Emissions	CO_2	CO_2 emissions (metric tons per capita)
Technology	TEC	(Patent applications, nonresidents+Patent applications, residents)/Population

Source: World Development Indicator (2023)

Next, the verification of the existence of a long-term cointegrating relationship is conducted through the use of the F statistic for a bound test. As indicated in Table 3, it is established that a long-term cointegrating variable is indeed present, as evidenced by an F statistic value of 4.325 exceeding the upper bound value derived from the 5% critical threshold. Thus, the outcomes for short and long run elasticities are ready to be discovered in the following stage of analysis.

The long-run elasticities, as presented in Table 4, are the central focus of our ARDL estimation. The findings reveal a noteworthy negative relationship between Gross Domestic Savings (GDS) and Public Debt (PD). When domestic savings rates are low, the government may find itself increasingly reliant on external borrowing, thus elevating public debt levels. Specifically, a 1% increase in GDS is associated with a 1.42% reduction in public debt.

Furthermore, Table 4 also highlights a negative and significant correlation between CO_2 emissions (CO_2) and Public Debt (PD). Poor environmental quality can necessitate heightened government expenditure. For instance, health issues resulting from pollution or environmental degradation may prompt the allocation of funds for healthcare and environmental remediation efforts. Such increased spending can contribute to budget deficits and, consequently, an escalation in public debt. Specifically, a 1% decline in environmental quality is associated with a 0.912% increase in public debt.

As for other variables such as economic growth, domestic investment, and technology, they exhibit a positive relationship with the level of debt. However, these relationships are not statistically significant at any level, indicating an absence of a concrete association and suggesting that they may not be influential factors in our policy recommendations.

The findings regarding short-term elasticity are presented in Table 5. In summary, only the 1-year lag of domestic savings demonstrates a significant association with public debt. Statistically, a 1% increase in domestic savings results in a 1.18% increase in public debt within the country. Conversely, the

Table 2: Unit root test results

Variable	ADF unit root Test			
	Intercept		Intercept+Trend	
	Level	1st Difference	Level	1st Difference
LNPD	−3.081 (0)**	−3.089 (4)**	−3.221 (0)*	−3.007 (4)
LNGDP	−0.389 (0)	−3.827 (0)***	−1.577 (0)	−3.737 (0)**
LNGDI	−4.076 (1)***	−5.831 (1)***	−3.954 (1)**	−5.712 (1)***
LNGDS	−2.887 (0)*	−6.274 (1)***	−3.312 (0)*	−6.148 (1)***
$LNCO_2$	−1.977 (0)	−5.847 (0)***	−3.474 (4)*	−5.832 (0)***
LNTEC	0.253 (6)	−4.801 (3)***	−7.709 (1)***	−9.202 (1)***
	PP Unit root test			
LNPD	−3.037 (2)**	−7.038 (4)***	−3.261 (1)*	−6.932 (4)***
LNGDP	−0.389 (0)	−3.740 (3)***	−1.774 (1)	−3.643 (3)**
LNGDI	−2.959 (8)*	−7.600 (28)***	−2.902 (8)	−8.392 (28)***
LNGDS	−2.887 (1)*	−13.159 (22)***	−3.350 (1)*	−11.975 (20)***
$LNCO_2$	−2.174 (7)	−9.519 (28)***	−4.590 (8)***	−12.576 (28)***
LNTEC	−3.632 (0)**	−9.665 (28)***	−13.567 (26)***	−13.126 (28)***

***, ** and *denote significance at 1%, 5% and 10%, respectively

Figure 3: CUSUM and CUSUM SQ

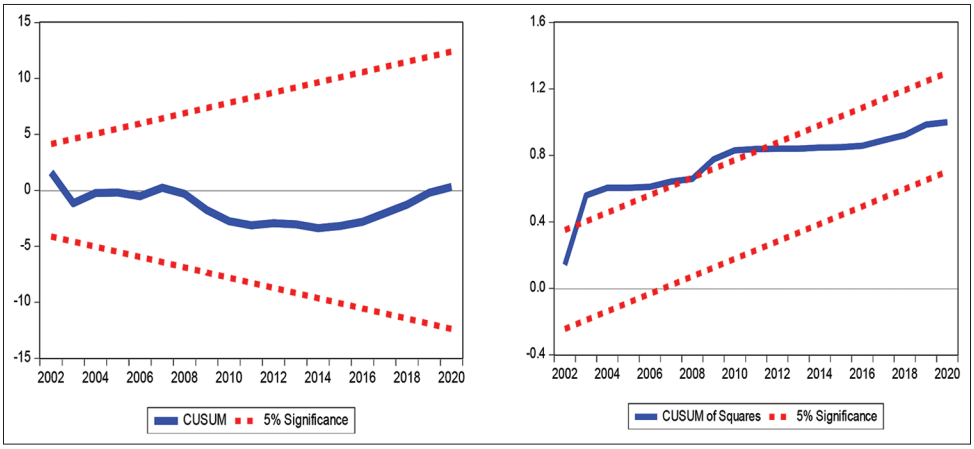


Table 3: Bound test

F-statistic	4.325**	Upper bound
Critical value	Lower bound	
10%	2.26	3.35
5%	2.62	3.79
1%	3.41	4.58

**denotes significance at 5%

Table 4: Long-run estimation results

Variable	Coefficient	Std. error	t-statistic	Prob
LNGDP	0.492	0.649	0.758	0.457
LNGDI	−0.001	0.049	−0.034	0.972
LNGDS	−1.420***	0.499	−2.843	0.010
$LNCO_2$	−0.912*	0.513	−1.777	0.091
LNTEC	0.230	0.206	1.114	0.278
C	3.152	3.270	0.963	0.347

***, and *denote significance at 1%, and 10%, respectively

Table 5: Short-run estimation results

Variable	Coefficient	Std. error	t-Statistic	Probability
D (LNGDP)	−3.152	2.323	−1.356	0.190
D (LNDI)	−0.002	0.064	−0.034	0.972
D (LNGDS)	−0.181	0.564	−0.322	0.750
D (LNGDS(−1))	1.180**	0.444	2.653	0.015
D ($LNCO_2$)	−1.180	0.700	−1.686	0.108
D (LNPAT)	0.297	0.261	1.138	0.269
CointEq(-1)	−1.293***	0.253	−5.105	0.000

**denote significance at 5%

Table 6: Diagnostic tests results

Test statistic	F-statistic	Probability
Breusch-Godfrey Serial Correlation LM	1.882	0.182
Ramsey RESET stability	0.564	0.462
Heteroscedasticity	1.279	0.309
Jarque-Bera	29.446***	0.000

***denote significance at 1%

remaining variables are not statistically significant and are thus deemed inconsequential for further assessment.

Additionally, it is noteworthy that the Error Correction Term (ECT) values exhibit a negative and significant sign, indicating a convergence of the variables in the long run. This convergence is a crucial criterion for effective policy recommendations.

The final step in the ARDL estimation procedure involves assessing the reliability of the proposed model through various diagnostic tests. The results, presented in Table 6, indicate that all diagnostic tests have been successfully met, with the exception of the Jarque-Bera normality test. It's important to note that passing the Jarque-Bera test is not mandatory for ARDL models due to their nature of capturing both past and present values.

In summary, the model is in good condition, as corroborated by the results of the CUSUM and CUSUM SQ tests shown in Figure 3. The fact that the blue dotted line falls within the 5% significance range between the two dotted lines provides assurance that the model remains stable over an extended period.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study conducts a comprehensive analysis of the determinants of public debt in both the short and long term, with a focus on Indonesia. Using ARDL analysis spanning from 1990 to 2020, it examines the interplay between Gross Domestic Savings, environmental quality, economic growth, domestic investment, technology, and public debt. The findings reveal that Gross Domestic Savings and investments in environmental quality negatively impact public debt, while economic growth, domestic investment, and technological advancements have a positive influence. Low domestic savings rates can lead to increased reliance on external borrowing, resulting in higher public debt levels. Moreover, the Error Correction Term (ECT) values show a significant, negative sign, indicating a long-term convergence of these variables.

To mitigate increasing public debt due to low savings, the government should encourage domestic savings through incentives and financial education. Simultaneously, the government should focus on environmental preservation by implementing measures to reduce CO_2 emissions and improve environmental quality, thereby minimizing healthcare costs and environmental cleanup

expenses. Diversifying revenue sources, adopting effective debt management strategies, and long-term fiscal planning are essential to reduce reliance on external borrowing and maintain fiscal discipline. Public awareness and education can play a pivotal role in fostering responsible individual and collective decisions. This holistic approach aims to manage public debt while advancing economic sustainability and environmental health.

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