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Innovation, Total Factor Productivity (TFP) and Economic Growth In Indonesia: ARDL Bound Test Approach

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Abstract:

This study aims to examine the cointegration relationship between innovation, TFP, and Indonesia's economic growth. The data used is secondary data in the form of a time series with a range of 1978–2019 sourced from WDI and PWT 10.0. The estimation technique uses the ARDL Bound Test Cointegration method. Empirical findings show that in the long term, innovation and TFP have a positive and significant influence on Indonesia's economicgrowth. In the short term, it is found that GDP lag-1, TFP, and trends have positiveimplications for driving Indonesia's economic growth. The balance of adjustments in the longterm is shown from the ECT value, and based on the bound test, it is found that there is a long-term cointegration relationship.

Keywords: *Innovation, TFP, economic growth, Indonesia.*

1. Introduction

Economic growth, especially as related to long-term sustainability, is still a relatively important topic and continues to attract attention as an object of study. Endogenous growth theory, Romer (1986), Lucas (1988), Grossman-Helpman (1991), and Aghion and Howitt (1990) emphasize the important role of innovation and technology as leverage factors in the economy in the long run. The link between innovation and economic growth has long attracted attention among researchers, academia, and the government. This concept is a topic that continues to be debated in various development literature by experts. This concept originates from growth theory developed by economists in the past, which shows that there is a relationship between innovation and economic growth in the long term.

The linkages between innovation activities and the economy can be explained through the introduction of various new things resulting from the development of

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innovative activities in the form of products, services, management, market scale, techniques, and knowledge that have new value and can have implications for increasing aggregate output. Most of the innovations resulted from the science sector or research and development (R&D). So to encourage economic growth, encourage innovation, R&D, and science. Apart from that, other main factors of economic growth come from technological advances, especially in the context of the current economy, which tends to be increasingly industrialized, making the role of technology in driving increased output increasingly important. The use oftechnology in economic activities encourages the efficiency and effectiveness of the production process so that more output is produced than before, which encourages economic growth. Theoretically, efficiency and technological development in the economy are reflected in the residual value of the production function, or what is called the Total Factor Productivity (TFP) in the Solow model. TFP is an output ratio that does not come from changes in labor or capital stock variables. This is thenused as an indicator of the efficiency of use and technological progress. In the theoryof endogenous growth, technology is explained as one of the main prerequisites for long-term economic growth, and its determination is not influenced by the law of diminishing returns to scale.

In the Indonesian context, the literature discussing the relationship between innovation, TFP, and economic growth is still very limited, so there is no clear indication of how these variables play a role in the economy, making it important to research the relationship between innovation, TFP, and economic growth. There have been several previous empirical studies showing the role of innovation and technology activities in economic activity. A study by Saleem et al. (2019) showed a positive impetus for innovation and TFP for Pakistan's economic growth in both the short and long term. Pecea et al.'s (2015) study found that there is a positive and significant relationship between innovation and economic growth in CEE countries (Poland, the Czech Republic, and Hungary). However, most of the previous research came from outside Indonesia, and on the other hand, previous studies related to economic growth in Indonesia also mostly focused on driving capital and labor factors and tended to ignore the factors of innovation and technological progress, especially at the macro level. The estimation technique uses the auto-regressive distributed lag (ARDL) approach, which is more fractional in statistical estimation and can resolve potential endogeneity in the model so that consistent and efficient estimates will be obtained. The novelty of this study is the period and research location. The empirical findings in this study show a positive relationship between innovation, TFP, and economic growth in Indonesia and suggest continuing to push for policies that are more innovation and knowledge-friendly.

This article is organized as follows: the second part is a literature review; the third part is data and research methods; the fourth part is results and discussion; and the last section is suggestions and conclusions.

2. Literature Review

The Solow growth model shows how growth in capital stock, growth in the labor force, and technological advances interact with the economy and how they affect the output of goods and services in a country as a whole (Mankiw, 2010). The model explains that economic growth depends on the addition of capital stock (through savings and investment), increases in the quantity and quality of labor (through population growth and education), and technological advances, which are assumed to be exogenous variables that increase over time, so the Solow model is sometimes also called the Solow model. exogenous growth (exogenous growth model) because the level of technological progress is not influenced by other factors in the economic system. In this model, technology is knowledge related to methods or how to produce something most efficiently, so the technological factor is defined as thelevel of efficiency and also technological progress.

Efficiency and technological development in the economy is reflected in the residual value of the production function, or what is called the Total Factor Productivity (TFP) in the Solow model. TFP is an output ratio that does not come from changesin labor or capital stock variables. This is then used as an indicator of the efficiency of use and technological progress. In the theory of endogenous growth, technology isexplained as one of the main prerequisites for long-term economic growth, and its determination is not influenced by the law of diminishing returns to scale. Endogenous growth theory: Romer (1990), Agion, and Howitt (1990) explain that TFP growth is determined by the economic system through the innovation decisions of economic actors by allocating some resources to the science, development, or R&D sector. Solow shows in his article that the increase in output can result from anincrease in the number of effective workers, not from an actual increase in the number of workers, or, in short, that the level of output has increased with the same amount of input due to an increase in the level of labor productivity as a result of technological advances (knowledge or labor experience in the production process) atany time.

Previous empirical studies conducted by Saleem *et al.,* (2019) showed that there is a positive relationship between innovation, TFP, and economic growth in Pakistan. Pecea *et al.,* (2015) conducted an empirical study of the relationship between innovation and economic growth for CEE countries (Poland, the Czech Republic, and Hungary). Innovation indicators are measured using several variables, such as data on the number of patents, the number of trademarks, and R&D spending. The results of the study show that there is a positive relationship between economic growth and innovation.

The Relationship Between Innovation and Economic Growth

The concept of linkages between innovation and the economy was first introduced by Schumpeter in his growth theory. Schumpeter (1934) explained that the process of innovation and its actors, namely innovators and entrepreneurs, are the main

factors in economic progress. Economic development is a spontaneous and intermittent change in a circular flow channel that continues to repeat; disturbances to the conditions of economic balance always change and replace the previous equilibrium conditions. The main element of development lies in trying to make new combinations that contain various possibilities that exist in a steady state, and that combination appears in the form of innovation. This shows that innovation in the economic context has a quite strategic role in boosting productivity and output levels. Through innovative activities, new things of value are introduced in the form of relatively new products, services, organizations, markets, and techniques. Innovation activities are mainly driven and sourced from R&D activities because innovation is very dependent on the development of pure and applied science. Innovation is a form of implementation of the results of scientific production so that it can have a useful form, especially for the economy. Therefore, the development of innovation is one of the main prerequisites for driving a long-term modern economy, and based on this, the following hypothesis is built:
H1: It is suspected that innovation has a significant effect on Indonesia's economic growth.

The Relationship between TFP and Economic Growth

In the theory of growth, both classic and endogenous factors emphasize the important role played by technological progress, or TFP, as the main prerequisite forlong-term economic growth. Increased technological progress has effectively encouraged various advances, especially in the economic field, where the increasing use of technology will facilitate production activities and increase efficiency, and about this, there will also be an increase in the level of aggregate output. Technological progress in this case is related to the improvement of equipment, methods, knowledge, and equipment in terms of production, which can have implications for increasing worker productivity. Today, technological developments have taken place relatively quickly. This is due to the encouragement of rapiddevelopment in science, which is the main factor determining technological development.

How the development of TFP affects economic growth can be explained by increasing the productivity of workers in production activities due to better knowledge, methods, and equipment used by workers so that they can producehigher output than before. However, to obtain and optimize the growth effect resulting from technological advances, they must be accompanied by an increase in human capital because the use of high technology, especially in the economy, requires adequate abilities and skills. Based on this, the research hypothesis isarranged as follows:
H2: It is suspected that TFP has a significant effect on Indonesia's economic growth.

3. Methodology

The data used in this study is secondary data in the form of the 1988–2019 time series for Indonesia, namely GDP data, TFP, and the number of patents sourcedfrom the World Development Indicators (WDI) and Penn World Table 10.0 (PWT 10.0). The data is collected by downloading the official WDI and PWT 10.0 sites. For further descriptions regarding the variables used, see the following:

Table 1 Description of Variable Data

Variable	Definition	Source
Economics Growth (GDP)	The percentage increase in aggregate output in a year is based on the GDP value at constant prices.	WDI
Total Factor Productivity (TFP)	Technology progress index.	PWT 10.0
Innovation (INNOV)	Number of patent registrations	WDI

The empirical relationship between human capital, innovation, TFP, and economic growth is estimated using the Auto Regressive Distributed Lag (ARDL) method and the Bound Test developed by Pesaran et al. (2001) to see the dynamic relationship and long-term cointegration between variables. The use of the ARDL model is dueto several things: first, there is a potential endogeneity problem in the model used, namely the TFP and innovation variables. According to Pesaran and Shin (2001), the approach with the ARDL method will not be disturbed by the potential for endogeneity among the independent variables, so a value will still be obtained. efficient guessing; second, ARDL is better suited to provide robust and consistent estimates with small sample sizes; third, the ARDL method is the best approach if there is a mix of integration orders I(0) and I(1) in the variables.

An examination of the unit root of each variable was carried out at the beginning to see its stationary order using the Augmented Dickey-Fuller (ADF), Dickey-Fuller-GLS, and Philips-Perron (PP) approaches before the model was estimated using the ARDL approach. After testing the unit roots, the optimum lag is selected using the Akaike Information Criteria (AIC), Schwartz Information Criteria (SC), and Hannan-Quinn (HQ) criteria approaches. Then, to determine whether there is a long-term relationship between variables, a Bound test is carried out by comparing the resulting F-statistic values with the critical tabulated values from Narayan (2005). According to Pesaran et al. (2001) and Narayan (2005), the lower bound critical value assumes that the independent variables are integrated at I(0), and the upper bound critical value assumes that the independent variables are integrated at I(1). So the decision-making hypothesis is that if the F-statistic value is smaller than the lower-bound critical value, then the conclusion is that there is no long-term integration between variables; conversely, if the F-statistic value obtained is greater than the upper-bound critical value, it means that there is a long-term relationship between variables. However, if the F-statistic value is between the upper-bound and lower-bound critical values, it cannot be concluded. Then, to test the stability of the model, the CUSUM and CUSUMSQ tests are done. As for estimation, the linear equation that has been transformed into a logarithmic form can be arranged as follows:

$$\boxed{logGDP_t = \beta_0 + \beta_1 logTFP_t + \beta_2 logInnov_t + \varepsilon_t} \qquad 3.1$$

Then equation 3.1 is transformed into the ARDL model equation to estimate the long-term coefficients, which are arranged as follows:

$$\Delta logGDP_t = \beta_0 + \sum_{i=0}^{r1} \alpha_1 \Delta logGDP_{t-1} + \sum_{i=0}^{r1} \alpha_2 \Delta logTFP_{t-1} + \sum_{i=0}^{r2} \alpha_3 \Delta logInnov_{t-1} + \beta_1 logGDP_{t-1} + \beta_2 logTFP_{t-1} + \beta_3 logInnov_{t-1} + \omega_t$$

The short-term relationship is estimated using an error correction mechanism (ECM), while the equation is arranged as follows:

$$\Delta logGDP_t = \beta_0 + \sum_{i=1}^{r} a_1 \Delta logGDP_{t-1} + \sum_{i=1}^{r} a_2 \Delta logTFP_{t-1} + \sum_{i=1}^{r} a_1 \Delta logInnov_{t-1} + \vartheta\, ECM_{t-1} + \varepsilon_t$$

Where Δ is the operator *first difference*, ω is *the error term*, $\alpha_1, \alpha_2, \alpha_3$ is the short-term coefficient, $\beta_1, \beta_2, \beta_3$ is the long-term coefficient, ϑ is the coefficient of balance adjustment speed in the long run, GDP is Gross Domestic Product, TFP is total factor productivity, and Innov adalah innovation.

4. Empirical Findings/Results

Unit Root Test

Empirical analysis, especially for time-series data, should be checked for the stationarity of each variable at an early stage before estimation is carried out using the Dickey Fuller-GLS unit root test, Augmented Dickey-Fuller, and Philips-Perron. The results of the unit root test can be seen in the following table:

Table 2 Unit Root Test Results

Variable	Dickey-Fuller-GLS		Augmented Dickey-Fuller		Philips-Perron	
le	Level	First-Difference	Level	First-Difference	Level	First-Difference
LogGDP	-2.570	-4.716***	2.570	4.624***	-2.290	-4.582***
LogTFP	-1.609	-4.932***	-1.664	-4.969***	-1.949	-4.969***
LogINNOV	-3.333**	-6.763***	-3.304*	-6.597***	-3.304*	-13.840***

*note: *, **, *** indicate significance at 10%, 5%, and 1%, respectively.*
Source: processed data, 2023

Based on the test above, it can be seen that the logGDP and logTFP variables are not stationary at the level in all test methods (DF-GLS, ADF, and PP), while the only log variable, INNOV, is stationary at the level. Then, by testing the unit root on the first difference, it can be seen that all the statistical values of the variables are stationary in the second order. The difference in the order of stationarity of the variables indicates that the ARDL method is the appropriate one to use, especially to look at short-term and long-term cointegration relationships.

Cointegration Test

Then, cointegration testing was carried out using the Bound test approach by comparing the resulting F statistical values with the upper and lower limit values at each existing significance level. If the F statistic value is greater than the upper value, then there is a cointegration relationship; conversely, if the F statistic value is less than the lower limit value, there is no cointegration; and if the F statistic value is between the upper and lower limit values, it cannot be concluded. The results of the cointegration test with the Bound Test are as follows:

Table 3 Cointegration Test Result

Test Statistic	*Value*	*Signif.*	*Lower Bound*	*Upper Bound*
F-*Statistic*	5.774	10%	4.19	5.06
k	2	5%	4.87	5.85
		1%	6.34	7.52

Source: processed data, 2023

Based on the test results, the F-statistic value of 5.77 was greater than the lower value and lower than the upper value at the 5 percent significance level, so it could not be concluded. If using a significance level of 10 percent, the statistical F value is greater than the upper critical value, so it can be concluded that there is a long-term and short-term cointegration relationship.

Diagnostic Test

The specification of a fit model does not contain assumptions related to autocorrelation, heteroscedasticity, or non-normally distributed data so that it can produce inconsistent and efficient estimated values. The results of the model diagnostic test are as follows:

Table 4 Diagnostic Test Result

Test	**Prob.**
Serial-correlation	0.277
Heteroskedastisisity	0.121
Normality	0.665

Source: processed data, 2023

In Table 4, it can be seen that the chi-square probability value obtained from the Breuch-Pagan autocorrelation test is 0.28, which is greater than 0.05, which means that the model is free from serial autocorrelation problems. Then for the heteroscedasticity test, a chi-square probability value of 0.12 is greater than alpha 5 percent, so it can be concluded that there is no heteroscedasticity problem in the model used. The results of the normality test shows that the data used is normally distributed, as indicated by the probability value, which is 0.67 greater than an alpha of 5 percent. Based on some of the test results above, it shows that the specifications of the model used are good enough.

Stability Test

Model stability testing was carried out using the CUSUM and CUSUMSQ tests with a significance level of 5 percent. The test results are as follows:

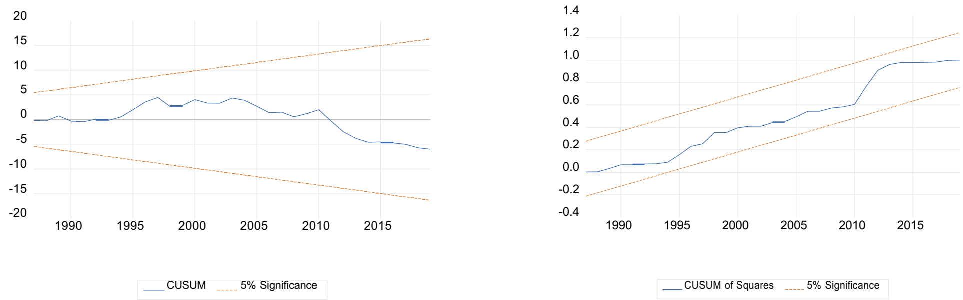

Figure 1 Plot CUSUM and CUSUMSQ

The CUSUM and CUSUMSQ test results in Figure 1 show that the model is relatively stable for use in determining long-term relationships between variables. This is shown from the CUSUM and CUSUMSQ lines (blue), which are between the5 percent significance line (red line) so it can be concluded that the model used is stable.

ARDL Estimation Result

The estimation results using the ARDL approach are presented in Table 5 in two parts, namely long-term and short-term results. In the table, it can be seen that the R-squared value obtained is equal to 0.81, which indicates that 81 percent of changesin economic growth variables can be explained by variations in changes in the dependent variable. This shows that the model used is relatively fit, while theparameters resulting from changes in each independent variable are as follows:

Table 5 ARDL Estimation Result

Variable	Koefisien	*Standard error*	*t-Statistic*	*Prob.*
Long run estimate				
LogTFP	0.479	0.063	7.561	0.000
LogInnov	0.055	0.021	2.574	0.015
Short term estimate				
ΔLogGDP(-1)	0.161	0.074	2.166	0.038
ΔLogTFP	0.437	0.050	8.788	0.000
@Trend	0.022	0.005	4.237	0.000
ECT(-1)	0.450	0.105	-4.286	0.000
R^2	0.810			
Adjusted R^2	0.789			
F-Statistic	37.430^{***}			

Source: processed data, 2023

5. Discussions

Based on the estimation results above, the TFP variable is indicated to have a positive and significant effect on economic growth both in the long and short term, where the coefficient value in the long term is 0.479, which means that a 1 percent increase in TFP will push GDP around 0.5 percent at a significance level of 5 percent. Meanwhile, the coefficient in the short term is 0.437, or a 1 percent increasein TFP will increase GDP by around 0.4 percent in the short term. These findings arein line with growth theory, which emphasizes the importance of technological progress, in this case, TFP, in driving economic growth, especially in the long term. Several previous studies conducted by Saleem et al. (2019) and Zhang et al. (2014) also showed that an increase in TFP had implications for boosting economic growth. Conceptually, the impetus for growth resulting from TFP on the economy can be explained through increased productivity, especially for workers in the production system, due to advances or changes in technology used, causing the production process to become more efficient and increasing the output produced compared to before. The relatively low level of technological progress, or TFP, in Indonesia when compared to other countries makes the growth effect resulting from each increase in TFP relatively large both in the short and long term. These findings indicate the important role of technology in the Indonesian economy, and what still needs to be considered is that encouraging technological progress, must always be followed by an increase in human capital to optimize the positive benefits provided by technological advances because high technology requires workers with qualified abilities. In the modern era, the development of technology and science moves relatively quickly, so technological adjustments in the production system are needed continuously through technological changes and the improvement of worker skills. In addition, the adoption of technology must continue to consider the surrounding socio-economic structure so that technological developments do not disrupt the economy.

The innovation variable was also found to have a positive and significant effect on economic growth in the long term, with a p-value of 0.02 < alpha 5 percent and a coefficient of 0.06, which means that a 1 percent increase in innovation activity will increase economic growth by 0.06 percent at a significance level of 5 percent. These findings confirm the research hypothesis and are in line with previous theories and studies by Saleem et al. (2019), Pece et al. (2015), Galindo et al. (2014), andPradhan et al. (2016), which found that innovation has a positive and significant effect on economic growth in the long term. This has provided clear indications regarding the positive role of innovation in the Indonesian economy, making it necessary to continue to encourage the science and R&D sectors, which are the basisof innovation activities, to obtain high and sustainable growth. In the short term, an increase in innovation activity may have negative implications for economic growth because the process of innovation becoming a product of new goods and services and other forms requires a large amount of time and resources, both labor and capital, to be allocated to research and development, or R&D. Capital allocation for R&D activities, both from individuals, households, companies, and state institutions,has implications for reducing investment capital so that there will be a temporary decline in the economy, but in the long term, the economy will boom again until the output from R&D is produced, begins to be applied in economic activities, and finally creates a growth boost for the economy.

In the short term, GDP (-1) is found to have a positive and significant influence on economic growth with a coefficient of determination of 0.16, or it can be concluded that every one percent increase in GDP (-1) encourages economic growth by 0.16 percent at a significance level of 5 percent. This shows that economic growth in the past, especially lag 1, played an important role in creating economic growth in the short term. Besides that, other factors that also have a positive and significant effect on economic growth in the short term come from the trend variable, so it can be concluded that any increase in time increases economic growth. The ECT variable statistically obtained a p-value of $0.00 < 0.05$ with a coefficient of 0.45, this value indicates the speed of balance adjustment in the long term after short-term shocks, which is 45 percent per year.

6. Conclusions

The problem of economic growth to date continues to be a challenge for several countries, both advanced economies and emerging markets, where emerging markets face poor growth and growth persistence problems in advanced economies. In the Indonesian context, economic growth in recent years has continued to show poor performance and has slowed down. If this continues to happen, it will potentially lead Indonesia to enter the middle-income trap and find it difficult to get out, so it is necessary to conduct studies related to the main factors that are the leverage of Indonesia's economic growth, especially in the long term. The purpose of this study is to examine the cointegration relationship between innovation, TFP, and Indonesia's economic growth using secondary data, namely the 1988–2019 time series, which originates from WDI and PWT 10.0. The estimation technique uses theARDL Bound Test method. The estimation results for the long term found that innovation activity and TFP had a positive and significant impact on Indonesia's economic growth, while in the short term, GDP (-1) and TFP and time trends found positive implications for driving economic growth. Based on the results of theBound Test, it was found that there is a cointegration relationship between TFP innovation and Indonesia's economic growth.

Based on the results of the research above, shows that to be able to encourage Indonesia's economic growth sustainably and to avoid the middle-income trap:

1. The Indonesian government needs to continue to encourage the optimization of national innovation systems and governance with policies that are more innovation-friendly to provide incentives for researchers, academics,

companies, and state R&D institutions to continue to innovate, such as ease of patent registration, R&D budget assistance, legal status, protection of innovation results, and various other stimulus policies.

2. The Indonesian government needs to first focus on improving aspects of science and human capital, which are key factors in the development of innovation and technology activities.
3. Technological improvements need to be adapted to the characteristics of the production system and the Indonesian economy so that they do not disrupt the economy in the long run. On the other hand, it is necessary to continue to make adjustments and updates to existing technology so that it remains relevant to production developments amid the rapid advances in technology, information, and science.
4. Then suggestions for further research are to focus more on the key determinants of innovation and technology and look for other modern variables that could be sources of new growth that must receive more attention and encouragement to achieve and maintain high economic growth in the future.

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