# Is the relationship between infrastructure and economic growth symmetric or asymmetric? evidence from Indonesia based on linear and non-linear ARDL

Maruf, Aminudin and Masih, Mansur

INCEIF, Malaysia, INCEIF, Malaysia

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# Is the relationship between infrastructure and economic growth symmetric or asymmetric? evidence from Indonesia based on linear and non-linear ARDL

Aminudin Maruf [1] and Mansur Masih[2]

**Abstract**

Although there are a number of studies on the relationship between infrastructure and economic growth, this study is the first attempt at investigating whether the relationship between infrastructure and economic growth is symmetric or asymmetric in Indonesia. Using the non-linear ARDL technique, this study employs quarterly data from 1990:Q1 – 2016:Q1. The paper finds a long-run asymmetric relationship between infrastructure and economic growth but symmetric relationship in the short-run. Moreover, this study also finds the causal direction of economic development in Indonesia from gross fixed capital formation to labor. The paper suggests the expansion of investment in the infrastructural industry to boost the growth of the Indonesian economy. The study also urges the policy makers to design robust infrastructure policies guiding the infrastructure and country's economy in both the short-run and long-run period.

**Keywords**: Infrastructure, Economic Growth, Non-Linear ARDL, Indonesia.

[1]Graduate student in Islamic finance at INCEIF, Lorong Universiti A, 59100 Kuala Lumpur, Malaysia.

[2] **Corresponding author**, Professor of Finance and Econometrics, INCEIF, Lorong Universiti A, 59100 Kuala Lumpur, Malaysia. Email: mansurmasih@inceif.org

## 1. Introduction

The problems of economic development, which are complex and multidimensional, have resulted in the development of a number of theories, explanations and arguments. Several economists had written extensively about the nature of economic society and prosperity. Adam Smith and Karl Marx are among the famous thinkers for their two opposite views on the nation's system of economic arrangements which are known as capitalism and socialism.

Looking back to the classical theories of economic development, there are a number of theories explaining factors of economic development, such as the Linear stages of Growth Models by Domar (1947), Harrod (1948), and Rostow (1960) which put the importance of investment to lead the economic growth. Structural Change Models, represented by two well-recognized representatives Lewis (1954) and Chenery (1960). The former is known for the two-sector model, while the later is known for the structural change and patterns of development. International Dependence Models and Neoclassical Counter-Revolution Models (Dang & Sui Pheng, 2015).

Additionally, contemporary theories of economic development are New Growth Theory which emerged in the 1990s explaining the poor performance of many less developed countries and Theory of Coordination Failure on the failure in achieving coordination among complementary activities. Subsequently, no single theory can explain the full concept of economic development.

Infrastructure as a key facilitator to sustainable economic growth is rarely questioned. Indonesia has charted impressive growth since demonstrating its resilience during the 2008 global financial crisis. As the world's fourth most populous country, Indonesia has maintained its gross national income per capita to steadily increases from USD857 in 2000 to USD3,603 in 2016 (KPMG, 2018). In the investment sector, Indonesia has implemented a series of economic policy packages which are aimed at stimulating investment and infrastructure improvements and also implementing regulatory reform. The world seems to be an optimist with Indonesia's business climate which resulted in a significant increase in investment (Cheng & Ramiaji, 2017).

On symmetric case, to the best of our knowledge neither theoretically nor empirically studies investigate this issue from the asymmetric and non-asymmetric aspect. Therefore, this paper makes an humble attempt to address this issue by relaxing the assumption of linearity and symmetry using the current advanced technique of Non-Linear ARDL (Shin, Yu, & Greenwood-Nimmo, 2014).

Based on the main conclusion of our study, we found that infrastructure has a long-run relationship to the economic growth, albeit of the asymmetric behavior found between both variables. However, it is found that the relationship between them are symmetric in the short-run and hence it is a good opportunity for the government to boost their economic growth. In addition, the variables are also cointegrated in the long-run which means that infrastructure might stimulate other factors such as labor and foreign direct investment.

Our findings would help policy makers and other stakeholders in different ways. The long-run asymmetric relationship between two aspects suggested the government to come up with the sound guidelines on the infrastructure investment. The cointegration of both aspects emphasizes the government of Indonesia to take action in developing its infrastructure and eradicate inequality of the economy. For other stakeholders, investment in infrastructure project might yield a higher and sustainable profit because of its relation in developing the domestic economy.

Finally, the rest of the study is structured as follows: the second section explores the theoretical framework of economic development followed by the third section on the literature review. Section four discusses the data and methodology of the study while section five investigates the empirical results and discussion of the study. Lastly the sixth section concludes the study with some recommendations.

## 2. Theoretical Underpinnings

The Indonesian economy has grown relatively well during the last two decades. Since the Asian Financial Crisis (AFC) in 1997/1998, the economy has grown by an average of around 5.5% per year, increasing the well-being of millions of Indonesians; while around 19% of Indonesia's population lived below the poverty line in early 2000, the figure is now less than 11%. The current open unemployment rate of 5.7% is also lower than the figure several years ago, indicating that the economy is managing to provide more jobs.

However, Indonesia's economic growth rate has been declining during the past few years, from 6.2% in 2011 to only around 5% currently. One of the defining factors is the end of the commodities boom, which took place in the period around 2003-2012. High global commodity prices boosted Indonesia's exports and fueled high economic growth. Now the economy cannot rely on commodity exports, but has to develop competitiveness in the manufacturing and services sectors. The development of those sectors, however, has been hampered by insufficient of quality infrastructure in Indonesia.

The availability of high infrastructure is very important in supporting economic development in at least two ways: it facilitates the development of new economic activities that leads to economic growth, while it also increases general quality of life and opens up opportunities to reduce inequalities and poverty incidence. Sufficient infrastructure would allow greater investment in the economy, create demand for employment activities. It also enables the development of human capital by providing access to healthier lifestyle and better education.

Without infrastructure support, private sectors need to develop their own supporting facilities before starting their business operations. That increases the cost of investment and reduces economic efficiency. Aware of the situation, President Joko Widodo has made infrastructure development his administration's priority by launching various development programs. The focus is on improving maritime connectivity, electrification, road and urban transportation, and agriculture irrigation. It is estimated that in order to achieve this goal, the country needs to invest Rp 5,500 trillion ($460 billion) in infrastructure within this five-year period.

Despite all the supporting factors, at least there are four key issues in the development of infrastructure that are still observed today which are: difficulties of financing and funding projects, it is known that the infrastructure development requires big amounts of capital. The government only manages to provide smaller portions of required funding. Moreover, the sustainability of financing is another issue of the infrastructure development.

Other than that, it is apparent that infrastructure in Indonesia requires greater private sector participation to fill the substantial financing gap. Which might lead to the issue of risk shifting from the government rather than risk sharing between the government and the private sectors. The high cost of infrastructure project and its length of time required for land acquisitions. Many infrastructure projects have been delayed for many years due to such problem. In addition, poor management of infrastructure project is reflected in the rapid rate of physical damage and high depreciation rate. Subsequently, the additional cost costs of reparation are high and the total depreciation value exceeds the amount of new investment in the same period.

Since evidently there is no conclusive result on whether infrastructure offers an economic growth, and this possibly could be because lack of research in this areas. Thus, in this study we want to investigate the driving aspect of infrastructure to economic growth by using the nonlinear ARDL technique by Shin et al., (2014) to reach for an empirical answer for determination of possible asymmetric and nonlinear relationship between infrastructure and economic growth.

## 3. Review of Literature

As mentioned above, past researchers show indecisive result in determining the role of infrastructure as a driving aspect of economic growth. Through mixed numbers of findings in the literature, we will first elaborate the positive relationship between infrastructure and economic growth and followed by the lack of relationship between both aspects. Lastly, we will analyze the possible linkage between infrastructure and economic growth to better understand the bigger picture of asymmetric relationship between the two variables.

To begin with, Herranz-Loncán (2007), Kodongo & Ojah (2016) and Pradhan & Bagchi (2013) provide evidence that infrastructure gives a significant and positive relationship to the growthof the economy. The conducted the study for Spain, India and Sub-Saharan Africa. Based on the VECM model, Pradhan & Bagchi (2013) suggest that expansion of transport infrastructure will lead to substantial growth of the Indian economy. Different from the previous study, Kodongo & Ojah (2016) confirm their result using GMM system that infrastructure spending is important for the developing countries to boost their economy. Using the same method, Saidi, Shahbaz, & Akhtar (2018) found in their study that transport energy consumption also significantly adds to economic growth in MENA, N-GCC and MATE regions. Taking note that we did not find in any literature of relationship between infrastructure and economic growth using the non-linear ARDL approach.

Using an accessibility approach, it is argue that accessibility improvement seems to be weakly but positively correlated with growth in regional employment. However, relaxing the linearity assumption, accessibility improvement does not have a statistically significant impact on urban areas and its negatively correlated with output growth of rural areas (Rokicki & Stępniak, 2018). Slightly different from others, Holmgren & Merkel (2017) consider that investing in infrastructure is seen as an important part of economic policy. It is often presented as a solution to a number of problems such as unemployment, depopulation of rural areas and ow economic activities.

As one of the most populous nations in the world, by taking a study on the period of 1995-2013 India shows that both economic and social infrastructure have a positive linkage with the growth of the economy in the country (Kumari & Sharma, 2017). Considering direct and indirect effects of the economic growth, Fedderke, Perkins, & Luiz (2006) found in their study that investment infrastructure seems to lead the economic growth in South Africa and affected to it directly and indirectly.

Interestingly, a massive infrastructure spending has not always translated into faster growth of economy. Negative marginal contributions of infrastructure also suggested because of over investment in some types of infrastructure in some regions during certain periods of time. This indicates that only more infrastructure is not always better to the economy, too much infrastructure investment can even detrimental to growth (Y. Shi, Guo, & Sun, 2017). Government of a country must be cautious not to over-rely on infrastructure investment as a means to revive its economy or narrow the gap between its developed and undeveloped regions. Moreover, based on Chinese provincial data over 1995-2011 it also be important to evaluate the fiscal risk that the current stimulus package will bring to the local governments in future (H. Shi & Huang, 2014).

According to the above discussion, prior studies tend to find mixed on inconclusive results depending on different regulatory policy, structural reforms and economic stability and equality across different nations. On the asymmetric relationship between infrastructure and economic growth, to the best of our knowledge we find lack of attention in this area. Due to this, this study intends to fill the gap of literature by making a step further addressing this issue using the NARDL framework.

4. Data and Methodology

For the empirical analysis, this study utilize quarterly Indonesian data covering sample time period from 1990:Q1 to 2016:Q1 with 105 observations. In order to represents an enrichment to the existing literature, this study employs five different variables whereby we zoom in to focus on the relationship between Gross Domestic Product (GDP) as a proxy for economic growth and Gross Fixed Capital Formation (GFCP) as a proxy for infrastructure. Based on the data availability in the database, we ensure that we the longest possible data span taking into account the crisis period. Apart from the focus variables, Gross Fixed Capital Formation Private Sector (GFCP_PS), Labor (LABOUR) and Foreign Direct Investment (FDI) are added as control variables.

The empirical methodology used in this paper begins with the unit root test to examine whether the variables are either stationary I(0) or first order difference-stationary (non-stationary) I(1). To test co-integration, this paper used Augmented Dickey Fuller Unit Root Test and Phillips-Perron tests in order to proceed with Engle & Granger (1987) and Johansen (1991) co-integration tests. However, due to mixed results found in ADF and PP tests, this paper compelled to move to the ARDL co-integration test that was introduced by Pesaran & Shin (1999) and later extended by (Pesaran, Shin, & Smith, 2001) which can comprise of both I(0) and I(1). To check the non-linearity between variables, this paper use the Non-linear ARDL (NARDL) co-integration test approached by Shin et al., (2014) to capture the short-run and long-run asymmetries through both positive and negative partial sum decomposition of changes in the focus variables. Then we proceed with the Granger-causality testing to examine the causality chain between the Gross Domestic Product (GDP), Gross Fixed Capital Formation (GFCP), Gross Fixed Capital Formation Private Sector (GFCP_PS), Labor (LABOUR) and Foreign Direct Investment (FDI).

**Table 1**
Descriptive Statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| lgdp | 105 | 8.647752 | 0.5571441 | 7.698608 | 9.475765 |
| lgfcp | 105 | 8.070986 | 0.5855157 | 6.954537 | 9.003096 |
| lgfcp_ps | 105 | 8.771712 | 0.5536893 | 7.835635 | 9.606403 |
| llabour | 105 | 1.808768 | 0.0151281 | 1.774943 | 1.82791 |
| lfdi | 105 | -0.5051131 | 0.0446643 | -0.5814897 | -0.4107209 |

## 5. Empirical Results and Discussion

### 5.1. Unit root test

Unit root test is essential to examine whether the variables are either stationary I(0) or non-stationary I(1) before proceeding to the co-integration tests. This is because most of the finance and economics variables are non-stationary in their original form. To check the stationarity of the variables we use Augmented Dicky-Fuller test (ADF), Phillips-Perron test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Stationary Test.

**Table 2**
Augmented Dickey Fuller Unit Root Test

| Series in Logarithms | Include an intercept and a linear trend | | | | |
|---|---|---|---|---|---|
| | ADF | Value | T-Statistics | Critical Value | Outcome |
| LGDP | ADF (4) = SBC | 175.9816 | -1.1481 | -3.3792 | Non-Stationary |
| | ADF (4) = AIC | 185.0645 | -1.1481 | -3.3792 | Non-Stationary |
| LGFCP | ADF (1) = SBC | 117.3386 | -1.8941 | -3.3842 | Non-Stationary |
| | ADF (1) = AIC | 122.5288 | -1.8941 | -3.3842 | Non-Stationary |
| LGFCP_PS | ADF (5) = SBC | 267.6977 | -1.3882 | -3.3809 | Non-Stationary |
| | ADF (5) = AIC | 278.0782 | -1.3882 | -3.3809 | Non-Stationary |
| LLABOUR | ADF (1) = SBC | 715.8653 | -2.5579 | -3.3842 | Non-Stationary |
| | ADF (1) = AIC | 721.0556 | -2.5579 | -3.3842 | Non-Stationary |
| LFDI | ADF (1) = SBC | 291.0836 | -3.7056 | -3.3842 | Stationary |
| | ADF (1) = AIC | 291.2738 | -3.7056 | -3.3842 | Stationary |
| Series in first difference | Include an intercept but not a trend | | | | |
| | ADF | Value | T-Statistics | Critical Value | Outcome |
| DGDP | ADF (3) = SBC | 176.6920 | -3.8141 | -2.8730 | Stationary |
| | ADF (5) = AIC | 184.5137 | -4.6406 | -2.8623 | Stationary |
| DGFCP | ADF (1) = SBC | 116.1655 | -7.9570 | -2.9413 | Stationary |
| | ADF (1) = AIC | 120.0429 | -7.9570 | -2.9413 | Stationary |
| DGFCP_PS | ADF (4) = SBC | 266.7566 | -3.0384 | -2.8726 | Stationary |
| | ADF (4) = AIC | 274.5115 | -3.0384 | -2.8726 | Stationary |
| DLABOUR | ADF (1) = SBC | 706.2539 | -3.1463 | -2.9413 | Stationary |
| | ADF (1) = AIC | 710.1314 | -3.1463 | -2.9413 | Stationary |
| DFDI | ADF (1) = SBC | 283.8698 | -3.5135 | -2.9413 | Stationary |
| | ADF (1) = AIC | 287.7473 | -3.5135 | -2.9413 | Stationary |

Notes: The ADF is used to test the stationarity of the variables both in log form and difference form. The null hypothesis states that variables are non-stationary. Hence, when T-statistics (at 95% level of confidence) is less than the critical value (in absolute term), we conclude that the variable as non-stationary. Conversely, when the T-statistic is greater than the critical value, we reject the null and conclude the variable is stationary.

**Table 3**
Phillips-Perron Unit Root Test

| | Include an intercept and a linear trend | | | Series in | Include an intercept but not a trend | | |
|---|---|---|---|---|---|---|---|
| Series in logarithms | T - Statistic | Critical Value | Outcome | first difference | T- Statistic | Critical Value | Outcome |
| LGDP | -0.98197 | -3.4518 | Non-Stationary | DGDP | -11.3132 | -2.9643 | Stationary |
| LGFCP | -4.8334 | -3.4518 | Stationary | DGFCP | -15.7772 | -2.9643 | Stationary |
| LGFCP_PS | -1.2173 | -3.4518 | Non-Stationary | DGFCP_PS | -3.9259 | -2.9643 | Stationary |
| LLABOUR | -1.7164 | -3.4518 | Non-Stationary | DLABOUR | -1.2614 | -2.9643 | Non-Stationary |
| LFDI | -2.0492 | -3.4518 | Non-Stationary | DFDI | -2.9483 | -2.9643 | Non-Stationary |

Notes: The PP is used to test the stationarity of the variables both in log form and difference from. The null hypothesis states that variables are non-stationary. Thus, when T-statistics (at 95% confidence level) is less than the critical value (in absolute term), we conclude that the variable as non-stationary. In contrary, when the T-statistic is bigger than the critical value, we reject the null and conclude that the variable as stationary.

ADF test was introduced in 1981 to handle the serial correlation that presence in the residuals which may cause biased empirical results (Dickey & Fuller, 1979). The rational idea behind ADF test is to include enough number of lagged dependent variables to rid average errors as well as to correct for residual autocorrelation problem (Dickey & Fuller, 1981). The ADF test can handle the ARMA errors in the variables as well as the characteristic of time-series data such as trends or breaks. Similar to ADF test, PP test also used for stationarity test however it differs from ADF by correcting both the autocorrelation and heteroscedasticity problems by using Newey-west adjusted variance method (Phillips, 1988).

To begin with, the variables are transformed into logarithms to make the variance stationary. Stationarity is derived when the variables have constant mean and finite variance. The findings (Table 2) suggest that all examined variables except FDI are not significant at 5 percent level, thus the null hypothesis of non-stationarity cannot be rejected. Subsequently all variables turn out to be stationary in their first differences. Since ADF test only correct the Autocorrelation problem, we then proceed with the second unit root test for robustness, we found that all variables except GFCP are not stationary in their log level form and become stationary with the exception of Labor and FDI.

**Table 4**
Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Stationary Test

| | Include an intercept and a linear trend | | | Series in first difference | Include an intercept but not a trend | | |
|---|---|---|---|---|---|---|---|
| Series in logarithms | T - Statistic | Critical Value | Outcome | | T- Statistic | Critical Value | Outcome |
| LGDP | 0.12986 | 0.14145 | Stationary | DGDP | 0.24948 | 0.39901 | Stationary |
| LGFCP | 0.10016 | 0.14145 | Stationary | DGFCP | 0.13234 | 0.39901 | Stationary |
| LGFCP_PS | 0.072913 | 0.14145 | Stationary | DGFCP_PS | 0.15885 | 0.39901 | Stationary |
| LLABOUR | 0.15929 | 0.14145 | Non-Stationary | DLABOUR | 0.45635 | 0.39901 | Non-Stationary |
| LFDI | 0.079323 | 0.14145 | Stationary | DFDI | 0.1034 | 0.39901 | Stationary |

Notes: The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) is used to test the stationarity of the variables both in log form and difference form. The null hypothesis is different from the previous two unit root tests as the variables is stationary when T-Statistics (at 95% confidence level) is lesser than the critical value, otherwise – non-stationary.

KPSS is also applied, the result from Table 4 shows consistency with the non-stationarity of Labor. Therefore, the outcomes from KPSS test cannot be used to proceed with Granger Causality test as the estimation might be mis specified. For this reason, we will conduct cointegration test using all variables that could be taken as I(1) on the basis of ADF test.

5.2. VAR order selection

**Table 5**
Test statistics and Choice Criteria for Selecting the Order of the VAR model

| No of Order | Selection Criteria | |
|---|---|---|
| | SBC | AIC |
| 1 | 1563.2 | 1602.1 |

Before going to co-integration tests, this paper attempts to carry out the order (lags) of vector autoregressive (VAR). Table 5 shows that both Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC) give one lag. Therefore, this paper will used one lag to proceed to the next steps.

5.3.Co-integration tests

5.3.1. Co-integration test: Engle-Granger

**Table 6**
Engle-Granger Cointegration Test

| OLS regression of LGDP on other variables | Unit root tests for residuals | | | | |
|---|---|---|---|---|---|
| | ADF | Value | T-Statistics | Critical Value | Outcome |
| LGDP | ADF (4) = SBC | 189.4508 | -3.0023 | -4.5584 | No Cointegration |
| | ADF (5) = AIC | 196.5489 | -2.5454 | -4.5584 | No Cointegration |

Notes: The Engle-Granger test checks whether the variables are moving together (cointegrated) or not. The error term would be stationary, when its test statistic is greater than the critical value at 95% confidence interval and thus proving cointegrating relationship.

We applied standard Engle Granger cointegration test in order to verify whether the variables are theoretically related, converging together over the long term. Any proof of cointegration implies that the relationship among the variables are in fact not spurious. According to Table 6, the test shows no cointegration between the variables and it does not move together in the long run. However, there are certain limitations within this method. There are issues on the order of the variables, since it cannot indicate which variable as dependent variable. Not only that, it can only test the presence of one cointegration relationship. Engle Granger use residuals from a single relationship thus it cannot treat possibility of more than one cointegration. Lastly, the technique relies on two estimators. It will generate the residual series and estimate regression for stationarity. Thus, error in the first estimation can be transmitted into the second one.

5.3.2. Co-integration test: Johansen

**Table 7**
Johansen Cointegration Test

| Test of the Stochastic Matrix | Cointegration with unrestricted intercepts and restricted trends in the VAR | | | | | |
|---|---|---|---|---|---|---|
| | Null | Alternative | Statistic | 95% Critical Value | 90% Critical Value | Outcome |
| Maximal Eigenvalue | r = 0 | r = 1 | 86.6952 | 37.8600 | 35.0400 | 1 Cointegration |
| | r <= 1 | r = 2 | 26.8784 | 31.7900 | 29.1300 | |
| Trace Statistics | r = 0 | r = 1 | 149.9482 | 87.1700 | 82.8800 | 2 Cointegrations |
| | r <= 1 | r = 2 | 63.253 | 63.0000 | 59.1600 | |

Notes: The statistic refers to Johansen's cointegration test based on unrestricted intercept and restricted trends in the VAR. From the above results, we choose one cointegrating vector according to eigenvalue tests statistics at 95% confidence interval. If the test is significant, we will reject the null hypothesis and accept the alternative which indicates an existence of cointegrating vectors.

To overcome the above weaknesses, we then implement Johansen's cointegration test. From Table 7, we conclude that there is at least one cointegration based on both Maximal Eigenvalue and Traces statistics. This denotes that each variable contains information for prediction of the other variables. The variable in our model consist of various macroeconomic determinants that can influence the economic growth. Accordingly, its long term relationship can give an intuitive implications that infrastructure will drive the economic growth in long run period.

Likewise, Johansen test comes with limitations as this test assume all variable are non-stationary. Correspondingly, the test is also sensitive to number of lags in the order of VAR whereby changes in order of lag can bring about to different results. In addition to that, the pretest is biased in favor of accepting the null at 95% of the time. We therefore want to overcome all these limitations problems by conducting ARDL technique as it can be applied regardless of whether the independent variables are I(0) or I(1).

### 5.3.3. Co-integration test: Autoregressive Distributed Lag (ARDL)

**Table 8**
Test of long-run relationship in ARDL

| Variable | F-Statistics | P-Value | 95% Critical Lower Bound | 95% Critical Upper Bound | Outcome |
|---|---|---|---|---|---|
| GDP | 6.5024 | 0.889 | 2.9816 | 4.1733 | Cointegration |
| GFCP | 13.7564 | 0.001 | 2.9816 | 4.1733 | Cointegration |
| GFCP_PS | 7.0189 | 0.672 | 2.9816 | 4.1733 | Cointegration |
| LABOUR | 1.6174 | 0.351 | 2.9816 | 4.1733 | No Cointegration |
| FDI | 3.0382 | 0.000 | 2.9816 | 4.1733 | Inconclusive |

Notes: The critical values are based on F table of (Pesaran et al., 2001), unrestricted intercept and trend with five regressors. If it is lesser than the lower bound, we fail to reject the null of no long run relationship among the variables, otherwise – there is long run relationship. If the values fall within the bound, the result is inconclusive. Based on this basis, unit rot test needs to be carried out.

From the limitations of Johansen co-integration test, this paper move to Autoregressive Distributed Lag (ARDL) which can deal with the variables that are stationary I(0) and non-stationary I(1). The null hypothesis in this ARDL co-integration test attempts to show that there is no co-integration between the variables, while the alternative hypothesis shows that there is a co-integration between the variables in the long run. This model is first introduced by Pesaran et al., (2001), this test also can perform better in determining cointegration using small sample size. The ARDL test involves two main stages:

The first stage is determining the existence of the long run relationship between the variables which is tested by computing F-statistic (Wald test). This is done by setting up each variable in turn as a dependent and testing whether the null hypothesis of non-cointegrating relation between the joint lagged levels of the right hand side of the model is significant or not. In that case, the computed F-statistic need to exceed the upper critical bound to confirm the presence of a long run relationship among the variables. From Table 8, it can be inferred that the computed F-statistic in GDP is above the 95% Critical Upper Bound rejecting the null of no long run relationship between the variables regardless of whether it is I(0) or I(1). This result indicates that infrastructure has a long run relationship to the growth of the economy in long run. Interestingly, the F-statistic for FDI lies between the 95% Critical Lower Bound and Upper Bound which indicates inconclusive result.

**Table 9**
Test of long-run coefficient in ARDL when LGDP is dependent variable

| Regressor | Coefficient | Standard Error | T-Ratio | P-Value |
|---|---|---|---|---|
| LGFCP | 0.021531 | 0.15436 | 0.13949 | 0.889 |
| LGFCP_PS | 0.80622 | 0.18702 | 4.3109 | 0.000 |
| LLABOUR | 7.1497 | 1.5597 | 4.5841 | 0.000 |
| LFDI | -0.44348 | 0.15183 | -2.9208 | 0.004 |

The second stage comprises of estimations of the long run coefficient and associated error correction model through ARDL and VECM. The error correction term taken from the model is a vital component I the study as it will unfold the process of short run adjustment back to long run equilibrium given a deviation from last quarter shocks. The intended lag is determined by SBC, AIC and adjusted LR test wherefore the estimated standard errors are obtained using the model selected by Schwarz Bayesian Criterion (SBC). The estimate of the long run coefficient are summarized in Table 9, it implies that GFCP_PS, LABOUR, and FDI have significant effects on the growth of economy.

From the test result above, LABOUR is the strongest determinant that can explain the economic growth. The coefficient of the Labor indicates that a 1% increase in Labor will rise the country's GDP by 7% on average, considering all other factors are equal. It is followed by GFCP_PS and FDI which has effect by 0.8 percent and downgrade the GDP by 0.4 percent. Not to forget, cointegration test whether there is a long-run relationship among the variables it does not unfold the process of short run adjustment to bring about the long run equilibrium. Thus, there could be possibility of short-run deviations from the long-run event.

5.3.4. Co-integration test: Non-Linear Autoregressive Distributed Lag (NARDL)

According to the traditional cointegration approach, the economic development (GDP) is expected to move proportionately and at the same speed with the decrease and increase of Gross fixed capital formation (GFCP). The reality might be different, the nonlinear and asymmetric relationship might happen between two variables. Hence, in our study we employ Non Linear ARDL which relaxes the assumption of linearity and symmetry. This technique developed by Shin et al., (2014) which can utilize positive and negative partial sum decomposition in order to distinguish possibilities of asymmetric effects in the short-run and long-run period.

NARDL enables us to explore the non-linear and asymmetric relationship between infrastructure and economic growth. NARDL has been used by Shahbaz, Hoang, Mahalik, & Roubaud (2017) in investigating the relationship of energy consumption, financial development and economic growth in India. In our study, the NARDL approach identifies the short-run and long-run relationship between GDP and GFCP. Non-linear ARDL model tests the long-run cointegration using bounds testing whereby the null hypothesis attempts to show that there is no long-run relationship between the variables. There is a long-run relationship of both variables when the F-statistics (Wald test) exceeds the critical value of upper bound.

**Table 10**
Non-Linear ARDL (NARDL) Statistical Test

| Variable | F-Statistics | Critical Lower Bound | Critical Upper Bound | Conclusion |
|---|---|---|---|---|
| GFCP | 16.6010 | 3.79 | 4.85 | Co-integration |

Notes: the result indicates that there is a co-integration between GDP and GFCP in the long-run at 5% significant level as the F-Statistics exceeds the critical value of upper bound.

Based on the above result, it is found that the F-Statistics (16.6010) is greater than the critical upper bound (4.89) which means that there is co-integration between GDP and GFCP in long-run. In other words, GDP and GFCP are moving together in long-run. Moving forward to the Wald test for long-run and short-run asymmetries, this study follows the general form of NARDL model introduced by Shin et al., (2014):

$$\Delta GDP_t = \beta_0 + \beta_1 GDP_{t-1} + \beta_2 GFCP^+_{t-1} + \beta_3 GFCP^-_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta GDP_{t-i}$$

$$+ \sum_{i=0}^{q} (\theta_i^+ \Delta GFCP^+_{t-i} + \theta_i^- \Delta GFCP^-_{t-i}) + u_t$$

Where GDP is a Gross Domestic Product and GFCP is Gross Fixed Capital Formation, p and q are the lag orders. NARDL will decompose gross fixed capital formation into its positive ($\Delta GFCP^{+}_{t-i}$ and negative $\Delta GFCP^{-}_{t-i}$ partial sums for increase and decreases. The null hypothesis in the NARDL test is that the relationship between GDP and GFCP is symmetry in short and long term period.

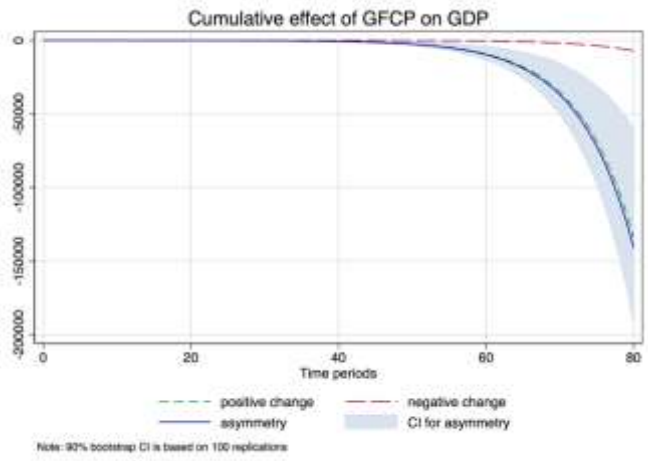
**Table 11**
NARDL Long-run and Short-run asymmetries

| Independent : GFCP | F-Statistics | P-Value | Selected Specification |
|---|---|---|---|
| Long-run | 17.25 | 0.000 | Asymmetry |
| Short-run | 0.03621 | 0.850 | Symmetry |

Notes: The table reports the long-run and short-run symmetry tests. The results are based on the NARDL equation. The null hypothesis is symmetry in short-run and long-run at 95% confidence level.

Based on the Wald test shown in the Table 11, the long-run P-Value is significant which indicates that the relationship between GDP and GFCP is asymmetry in the long-run. In contrary, the P-Value for short-run is more than 5 percent and therefore the relationship between GDP and GFCP is symmetry in short-run.

**Figure 1**: Gross Fixed Capital Formation and Gross Domestic Product




The graph above depicts the effect of gross fixed capital formation on gross domestic product, the logic behind short-run symmetric relationship is that Indonesian government can control the proportion of both aspects while in long-run it might be driven by the market which government has no much control over it, hence long-run asymmetry relationship of both variables take place. However, it is found in the earlier test that they are moving together which might suggest the government of Indonesia to maintain and monitor their infrastructure investment.

5.4. Long Run Structural Modeling (LRSM)

LRSM technique is conducted to bypass some of the major imitation of Granger causality. Since the conventional cointegration method is based upon estimation of cointegrating vectors that is not backed up by theory, LRSM will solve this issue through testing long-run coefficient of the variables against its theoretically expected value. This is done by imposing both exact and over identification restrictions grounded on the basis of theories and economics under review.

**Table 12**
LRSM Test

| Variable | **ML estimates subject to exactly identifying restriction(s)** | | | |
|---|---|---|---|---|
| A1=1 | Coefficient | Standard Error | T-Ratio | Outcome |
| LGDP | 1.0000 | None | None | None |
| LGFCP | -1.7719 | -0.51639 | 3.4313 | Significant |
| LGFCP_PS | 1.3174 | -0.59418 | 2.2171 | Significant |
| LLABOUR | -21.1966 | -4.8325 | 4.3862 | Significant |
| LFDI | 0.88483 | -0.2689 | 3.2905 | Significant |
| Variable | **ML estimates subject to over identifying restriction(s)** | | | |
| A1=1, A3=0 | Coefficient | Standard Error | T-Ratio | Outcome |
| LGDP | 1.0000 | None | None | None |
| LGFCP | -0.77307 | -0.095143 | 8.1253 | Significant |
| LGFCP_PS | 0.0000 | None | None | None |
| LLABOUR | -12.7051 | -1.2661 | 10.0348 | Significant |
| LFDI | 0.69477 | -0.15856 | 4.3817 | Significant |
| LR Test of Restrictions | CHSQ(1) = 18.8705 [0.000] | | | |

Notes: The result above shows the maximum likelihood estimates subject to exactly identifying and over identifying restrictions. In exact identification, we are normalizing the coefficients by imposing restriction 1 to our focus variable treated as dependent. Over identifying tests the computed long run coefficient against it theoretically expected values. The significant results are given in the result column in the table. When p-value is greater than 5%, we fail to reject the null hypothesis which suggests that the restriction is correct.

When we imposed an exact identification of unity on the coefficient of GDP in Table 10, we found that all variables are significant at 95 percent confidence interval. We then imposed over-identifying restriction of unity on the variable which has smallest T-Ratio. From the result it shows that all variables are remain significant. The null hypothesis of LRSM is the restriction is correct, looking at the result in table 10, the P-Value is less than five percent and therefore we reject the null and conclude that the restriction is not correct.

5.5. Vector Error Correction Model (VECM)

Vector Error Correction Model (VECM) indicates the direction of Granger causality, which variable is leading and which variable is lagging. It explains the exogenous and endogenous aspect of the variables. In addition, VECM also implies that changes in dependent variables are a function of the level of disequilibrium in the cointegrating relationship as well as changes in other variables. The variable is said to be exogenous if the corresponding dependent variable is insignificant and the variable is said to be endogenous if the corresponding variable is significant which refer to the error correction coefficient. The null hypothesis in the VECM attempts to show that the variables are exogenous and the alternative hypothesis shows it conversely.

**Table 13**
VECM Result

| Dependent Variable | ECM (-1) Coefficient | Standard Error | T-Ratio | P-Value | Critical Value | Outcome |
|---|---|---|---|---|---|---|
| dLGDP | -0.078024 | 0.04854 | -1.6074 | 0.111 | 5% | Exogenous |
| dLGFCP | 0.79763 | 0.11095 | 7.1894 | 0.000 | 5% | Endogenous |
| dLGFCP_PS | 0.025489 | 0.020573 | 1.239 | 0.218 | 5% | Exogenous |
| dLLABOUR | 0.6104 | 0.2215 | 0.27556 | 0.783 | 5% | Exogenous |
| dLFDI | -0.03507 | 0.016977 | -2.0657 | 0.042 | 5% | Endogenous |

Notes: The significant of p-value or t-ratio at 95% confidence level indicates whether the deviation from equilibrium give significant relationship or not on the dependent variable (GDP). If the error term coefficient is found to be significant, the corresponding variable is the follower (endogenous), otherwise – if its insignificant the corresponding variable is the leader (exogenous).

Table 11 shows that Gross Fixed Capital Formation (GFCP) and Foreign Direct Investment (FDI) are endogenous as the null hypothesis is rejected at 5 percent significant level. The ECM coefficient is not significant for Gross Domestic Product (GDP), Gross Fixed Capital Formation in Private Sector (GFCP_PS) and Labor (LABOUR), they are leading variables and do not depend on the deviation of other variables. The intuitive reason behind the exogeneity of GDP is that leakage in economy or it can be said that variable GDP does not cover all economic activities. On this basis, the foreign direct investment (FDI) is depending on other variables as an endogenous variable, the logic reason is that all FDI coming to the country depends on the country's economic situation. If the economic condition is good subsequently FDI will come and vice versa.

5.6. Variance Decomposition (VDC)

The VDC is a method used to analyze the relative degree of exogeneity and endogeneity of the variables. Through decomposition techniques, we will determine which variable is the most exogenous and which is the most endogenous by looking at the proportion attributable to its own past shocks. The variable that can be mostly explained by its own past is considered to be the ultimate leader (exogenous). From table 14 and 15 below, the Orthogonalized and Generalized VDC give different ranking of variables. The difference between both is that the Orthogonalized Variance Decomposition is not unique and in general depends on the particular ordering of the variables in the VAR but the Generalized Variance Decomposition is invariant to the ordering of the variables. Other than that, the Orthogonalized Variance Decomposition assumes that when a particular variable is shocked, the other variables in the system are more less switched off but the Generalized Variance Decomposition does not make such a restrictive assumption.

**Table 14**
Orthogonalized Forecast Error Variance Decomposition

| Variable | Relative Variance in Period 10 | | | | | |
|---|---|---|---|---|---|---|
| | LGDP | LGFCP | LGFCP_PS | LLABOUR | LFDI | Ranking |
| LGDP | 61% | 0% | 24% | 4% | 10% | 4 |
| LGFCP | 30% | 25% | 36% | 0% | 9% | 5 |
| LGFCP_PS | 10% | 0% | 87% | 0% | 3% | 2 |
| LLABOUR | 0% | 0% | 1% | 98% | 1% | 1 |
| LFDI | 3% | 7% | 6% | 0% | 84% | 3 |
| Variable | Relative Variance in Period 20 | | | | | |
| | LGDP | LGFCP | LGFCP_PS | LLABOUR | LFDI | Ranking |
| LGDP | 50% | 0% | 28% | 12% | 10% | 4 |
| LGFCP | 26% | 15% | 44% | 1% | 14% | 5 |
| LGFCP_PS | 10% | 0% | 85% | 0% | 4% | 2 |
| LLABOUR | 0% | 0% | 2% | 96% | 2% | 1 |
| LFDI | 3% | 8% | 7% | 1% | 81% | 3 |
| Variable | Relative Variance in Period 30 | | | | | |
| | LGDP | LGFCP | LGFCP_PS | LLABOUR | LFDI | Ranking |
| LGDP | 43% | 0% | 29% | 19% | 8% | 4 |
| LGFCP | 24% | 12% | 46% | 3% | 15% | 5 |
| LGFCP_PS | 10% | 0% | 84% | 0% | 5% | 2 |
| LLABOUR | 0% | 0% | 2% | 96% | 2% | 1 |
| LFDI | 3% | 8% | 7% | 1% | 80% | 3 |

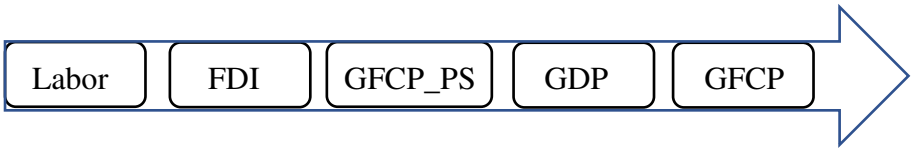
**Table 15**
Generalized Error Forecast Error Variance Decomposition

| Variable | Relative Variance in Period 10 | | | | | |
|---|---|---|---|---|---|---|
| | LGDP | LGFCP | LGFCP_PS | LLABOUR | LFDI | Ranking |
| LGDP | 59% | 10% | 13% | 7% | 10% | 4 |
| LGFCP | 27% | 37% | 24% | 0% | 12% | 5 |
| LGFCP_PS | 8% | 2% | 75% | 0% | 14% | 3 |
| LLABOUR | 0% | 0% | 1% | 98% | 1% | 1 |
| LFDI | 3% | 2% | 7% | 0% | 87% | 2 |
| Varriable | Relative Variance in Period 20 | | | | | |
| | LGDP | LGFCP | LGFCP_PS | LLABOUR | LFDI | |
| LGDP | 50% | 8% | 17% | 16% | 9% | 4 |
| LGFCP | 24% | 26% | 31% | 0% | 19% | 5 |
| LGFCP_PS | 8% | 2% | 73% | 0% | 17% | 3 |
| LLABOUR | 0% | 0% | 2% | 97% | 2% | 1 |
| LFDI | 3% | 3% | 8% | 1% | 85% | 2 |
| Variable | Relative Variance in Period 30 | | | | | |
| | LGDP | LGFCP | LGFCP_PS | LLABOUR | LFDI | |
| LGDP | 43% | 7% | 18% | 24% | 7% | 4 |
| LGFCP | 22% | 22% | 33% | 1% | 21% | 5 |
| LGFCP_PS | 8% | 2% | 72% | 1% | 18% | 3 |
| LLABOUR | 0% | 0% | 2% | 96% | 2% | 1 |
| LFDI | 3% | 3% | 9% | 2% | 84% | 2 |

Notes: Table 11 & 12, row read as the percentage of the variance of forecast error of each variable into propositions attributable to shocks from other variables, including its own. The column read as percentage in which variable contributes to other variables in explaining observed changes. The diagonal line of box (highlighted) shows the relative exogeneity.

Based on the explanation above, we consider that the Generalized Variance Decomposition is more reliable for this study. Hence, from the result of Generalized Variance Decomposition we found that the flow of the casual chain are as follows: Gross Fixed Capital Formation (22%), GDP (43%), Gross Fixed Capital Formation in Private Sector (72%), Foreign Direct Investment (84%) and Labor (96%). The findings reveal that Labor is the most leading variable and Gross Fixed Capital Formation is the most lagging variable. However, this result contradict our earlier results given by the error correction model that GDP is exogenous and FDI is endogenous.

**Figure 2:** Casual chain from exogenous (left) to endogenous (right)

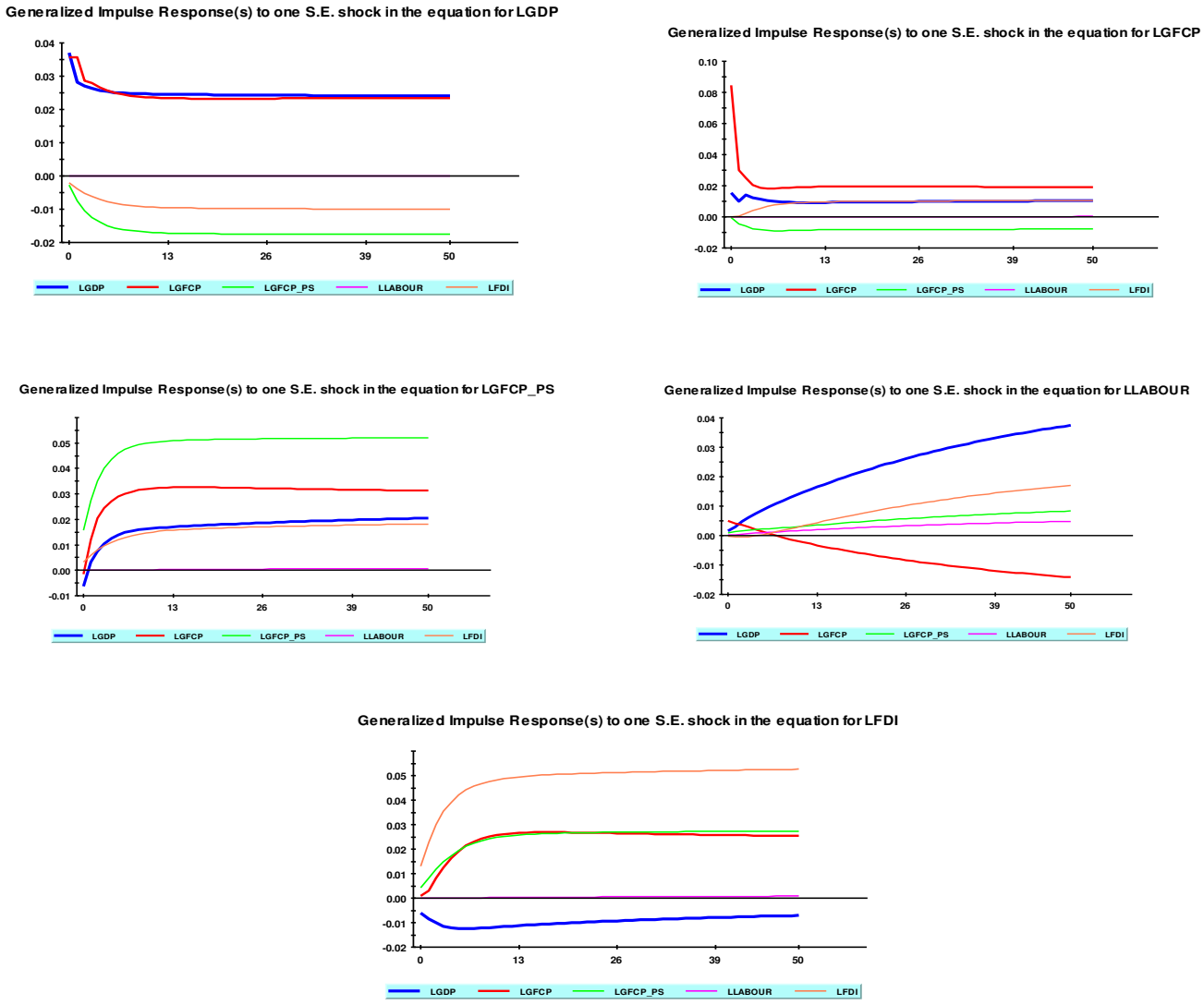



Labor turns out as the most exogenous variable which the rationality behind it is that man-driven factors cannot be influenced by other variables except the personality of the society. Following Labor as the second most exogenous variable FDI which is surely not under government control yet can be attracted by Indonesia's economic policy. Moreover, Indonesia as developing country has issued some investment policies to attract some FDI into the country. The investors tend to follow the biggest benefit they can get. Gross Fixed Capital Formation in Private Sector, Gross Domestic Product and Gross Fixed Capital Formation are coming after the two most exogenous respectively. This result support our intuition with the fact that the private sector is indeed not under government controls while the GDP and GFCP is fully under the control of the government.

5.7.Impulse Response Function (IRF)

We then applied the generalized IRFs which essentially maps the dynamic response of a variable's shock (from VDC) towards other variables and how long it take to normalize. Consistent with the earlier results, we found that Labor has the biggest impact on shock which is in line with our previous result as its most exogenous variable. Similarly, when FDI is being shocked, it also gives a huge response to the other variables. Other than these two variables, the shocks are relative significant but smaller than the previous two variables. If we look at the GFCP, we find that it has the weakest shock as it is the most endogenous variable.

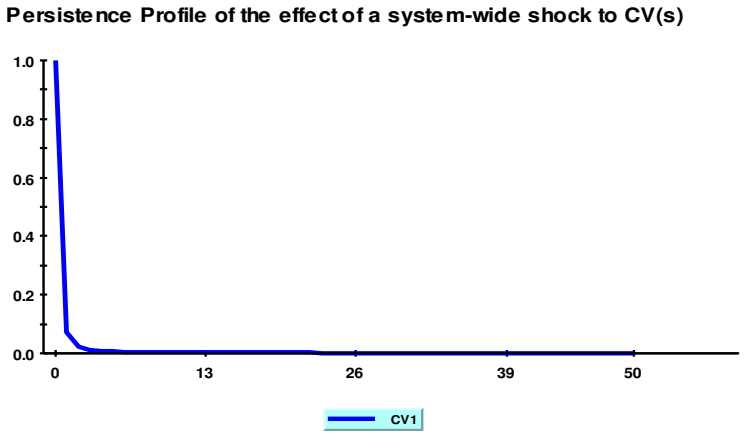
**Figure 3**: Generalized impulse response to one SE shock in all equations.




5.8.Persistence Profile (PP)

Different from Impulse Response Function (IRF) which use one specific variable shock to see the impact on other variables in the system, persistence Profile (PP) use a system-wide shock on the long-run relations among the variables to estimate how long it would take to get back to equilibrium if the entire co-integrating equation is shocked. From the figure below, it can be concluded that if the entire system is being shocked it will take 1 year (4 quarters) to get back to the equilibrium.

**Figure 4**: Persistence profile of the effect of a system-wide shock




6. Conclusion and Policy Recommendation

This study has investigated the presence of long-run relationship (cointegration) between infrastructure and economic growth in Indonesia using the quarterly data from 1990Q1 to 2016Q1 period. This paper is deemed to be pivotal aspect in designing the infrastructure policies in the present growing economy. Using the Non-linear ARDL cointegration and granger causality test, this study finds that infrastructure has a significant impact on the growth of the economy. Subsequently, the positive result of this study would be much better if it turns into some implementation from the government. Given the big population, Indonesia has a big potential in developing its economy in competing with other nations. As the largest archipelagic country in the world, infrastructure investment will be right solution for the government in connecting all the islands.

Although we cover the rising topic of the nation, some limitations of the study are need to be considered for future research. This study only limited to five macroeconomic variables namely gross domestic products, gross fixed capital formation, gross fixed capital formation in private sector, labor and foreign direct investment. There are other variables that might be included in further study such as trade openness and trade balance which could make the result more robust. Identically, the period of the study can be expanded to cater all economic events which have different effects on the study.

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