Does public infrastructure lead or lag GDP? evidence from Thailand based on NARDL

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10 December 2018

Does public infrastructure lead or lag GDP? evidence from Thailand based on NARDL

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Abstract

It is usually recognized that public infrastructure is an important ingredient for economic growth.. What is not clear, however, is the leader-follower relationship between them. This paper is focused on whether the infrastructure leads GDP or the other way around. Thailand is used as a case study. The methods used are the ARDL and nonlinear ARDL. The nonlinear ARDL analysis indicates that the cointegrating relationship between the two variables is nonlinear and that the relationship is asymmetric in both the short and long run. Furthermore, the findings based on variance decomposition analysis tend to indicate that infrastructure drives GDP and not the other way around. These findings appear to be intuitive and contain strong policy implications for the decision makers in an emerging economy like Thailand.

Keywords: Infrastructure ,GDP, ARDL, NARDL, VDC, Thailand

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Introduction

A prosperous economy requires a strong foundation at the root of the economy which is infrastructure. Infrastructure is one of the main ingredients to have on and economic plate to enhance productivity and economic growth. Aschauer (1989a, 1989b, 1989c) was one of the very first researchers to do empirical study on this issue. Many literature have found a positive effect of infrastructure investment on economic growth (Aschauer, 1989; Calderón and Servén, 2003; Canning and Pedroni, 2004; Easterly and Rebelo, 1993; Roller and Waverman, 2001; World Bank, 1994) and the same result for cross country studies by Canning and Peroni (1999). Economic growth is closely linked with infrastructure because it adds value to production and consumption. In recent times there have been many studies between the relationship of infrastructure investment on economic growth because it one of the most important duties that a government and academics need to keep prudent for economic policies.

This paper will raise two concerns, firstly is there a long term and short relationship between infrastructure investment and economic growth? Secondly what is the lead-lag position that causes this relation. This work will add value to the present literature on this topic. The focus country for this research is Thailand as there are minimal papers on empirical studies between infrastructure investment and economic growth.

Thailand's economic growth between 1957-1993 had a constant rate of 7 to 8 percent which has surpassed the upper-middle income country but from 1994 to present day, the constant rate decreased to 3 to 5 percent ("Thailand 4.0 MEANS OPPORTUNITY THAILAND", 2017).

Thailand's government economic development scheme *Thailand 4.0* focused on value-based and innovation driven by turning commodity producers to innovative products. Infrastructure is a major investment in this economic development scheme as railways, high speed rail, roads and upgrading the airport. Government initiatives is to make Thailand the hub for logistics as Thailand is connected to Malaysia, Myanmar, Cambodia and Laos which is a strategic point. This literature will help policy makes in Thailand understand the relationship of infrastructure with economic growth and which variables do the government need to focus on. The flow of this paper is divided

into 5 sections. The next sections discuses the theoretical framework followed by Data and Methodology. The last two sections an Empirical Results and Policy Implication and Conclusion.

Theoretical Framework

There are many issues that can cause economic. Solow model with human capital is a model that explain about economic production by having three inputs: labour, human capital and physical capital. Combining these three capitals with knowledge is known as technology fiving the production function:

$$Y = F(K, AH) = K^{\alpha}(AH)^{1-\alpha}$$

K is physical capital, A is labour-augmented technology progress and H is defined as:

$$H = e^{\psi u}L\,;\psi > 0$$

u is the fraction of a person's time in learning skills while $L$is the number of labour force? The equation tells us that a person will utilize human capital by spending time learning skills rather than working. The production function can be changed into output per person giving:

$$h = e^{\psi u}$$

Solo's model has the element of production and accumulation capital function giving:

$$K = s_K\dot{Y} - dK$$

Combining the two functions will give:

$$y^*(t) = hA(t)\left(\frac{s_K}{n+g+d}\right)^{\alpha/(1-\alpha)}$$

This is known as steady condition where a country can be rich if they have lots of investment captured by the variable s_K and h is the amount of time used to learn new skill and n is the growth rate of the population, A explains the technology level.

Neo classical growth theory proposed by Adam Smith states that infrastructure can lead to economic growth by using the Solow growth model as mentioned above (Moesketsi, 2017). Economic growth through infrastructure in a short run is influenced by savings and depreciation

rates while in the long run is influenced by population growth. If there is an increase in infrastructure investment, it will increase growth temporary because the ratio of capital to labour inputs increases but an additional infrastructure capital will decrease in the long run economic growth as real GDP grows at the same rate as the workforce growth. Therefore, to have economic growth, neo classical economists believe that labour input supply must increase followed by an increase in level of labour input and the infrastructure.

Literature Review

Past studies have concluded the study of infrastructure on economic growth with a positive and significant impact. There are also studies that found a negative impact of infrastructure investment economic growth because communication and transportation expenses in the 43 countries by the government expenditure was unproductive (Devrajan et al. ,1996). The paper further concluded the positive effect of increasing shares of consumption expenditures while a negative impact on increase of public investment. A causality study by Canning and Peroni (1999,2004) to determine the relationship between investment for different types of economic infrastructure with GDP. Granger causality test was applied using panel data of 67 countries from 1960-1990. The authors found a two-way causality on the relationship in most of the countries. Another study by the same authors on long run relationship of infrastructure growth to GDP finds that infrastructure reduced long term growth in most of the countries, but a significant long-term effect is only found in some countries at an individual level. The further concluded that overall relationship is negligible at average amongst the countries.

A study using ARDL and VECM by Fedderke and Bogeti (2006) found a positive impact of infrastructure to labour productivity that is involved with railway and port infrastructure while telecommunication and road infrastructure had a negative impact. Murty and Soumya (2006) studied macroeconomics effects of changes in public infrastructure investment in India using macroeconomics variables which relates to real, fiscal, external and monetary sectors. The study found a crowding in effect in all the sectors and public investment in infrastructure gave impact to economic growth. Sahoo and Dash (2008) used gross domestic capital formation per capita as a proxy for infrastructure capital to estimate the impact in four South Asian countries. The study reports a positive impact to economic growth.

Sahoo, Dash and Nataraj (2010) reported a study in China on the role of infrastructure to promote economic growth using ARDL, GMM and VECM to find causality. The result found no causality between infrastructure investment and economic growth but positive impact to China's economic growth. Another study in China by Nannan et al. (2012) using OLS found physical infrastructure gave impact to growth but does not cover the demand in the economy. A study in focusing on South Africa by Kumo (2012) used ARDL and Bivariate vector Auto regression model applying structural break to find causality between economic infrastructure investment and employment in public sector. The result found two-way causality relationship and long-term relationship in ARDL and concludes the long-term relationship between economic growth with, infrastructure investment, exports, imports and employment.

Data and Methodology

Data for this study is collected from the World Bank Data covering 43 years starting from 1974 using annual data type and based on data availability in the database. The table below gives a summary to the variables used in this study:

Variable	Symbol	Proxy
Gross Domestic Product	GDP	Economic Growth
Consumer Price Index	CPI	Inflation
Revenue, Excluding Grants	REV	Government Revenue
Employment Rate	EMP	Employment
Gross Fixed Capital Formation	GFCF	Infrastructure Investment
Gross Fixed Capital Formation Private Sector	GFCFP	Infrastructure Investment in private sector
Trade Openness	TO	Ratio of total trade to GDP

Table 1: Variables

Times series technique will be applied consisting of unit root test, cointegration test, LRSM, VECM and VDC. A more advanced cointegrating technique such as ARDL and NARDL will be applied for this paper.

Cointegration test for Engle-Granger and Johansen requires the variables to be nonstationary. To test for stationary, we apply the unit root test by turning all your variables to log form and the differenced of the log form. A variable is set to be stationary when the variance, covariance and mean are constant. There are three tests that can be performed to test for stationarity in time series: Augmented Dickey-Fuller (ADF), Kwiatkowski–Phillips–Schmidt–Shin (KPSS) and Phillips and Perron (PP). The null hypothesis for KPSS is the variable is stationary while the null hypothesis for ADF and PP is that it is not stationary. ADF test takes care of autocorrelation only while PP test takes care of autocorrelation and heteroscedasticity.

Cointegration Test

After stationarity test, VAR order selection is performed to find the optimum number of lags required for the research. The lag order selection is important because choosing different lag order can give different result in Johansen cointegration. After selecting lag order, cointegration test is applied, Engle-Granger and Johansen test. Engle-Granger determines whether variables are theoretically related by examining the error term. There is cointegration when the residual of cointegration relationship is stationary (Engle and Granger, 1987). There are two limitations of Engle Granger first, they can only identify one cointegration, second Engle-Granger requires a two-step process where one regression estimate residuals and a second regression for unit root test. Johansen is another cointegration that can identify more than one cointegration based on maximum likelihood (Johansen,1991). The limitation for Johansen test is the assumption of variables are I(1). Cointegration is important test as they confirm the relationships between the variables are not spurious however, both Engle-Granger and Johansen cointegration test have weakness where they require all variables in the research to be non-stationary and the test depends on the lag order chosen and whether the researcher have included a trend or not.

ARDL

Due to the limitation in Engle-Granger and Johansen cointegration test, Autoregressive Distributed Lag (ARDL) is more advance technique introduced by Pesaran et al. (2001) to apply in time series. Unlike Engle-Granger and Johansen cointegration test, ARDL does not require to test the variables in their stationary form. ARDL is a cointegration test that can cater small sample size where the long run relationship is through Wald test (F-test). F-test will determine if there is a long run relationship between the variables where the F-test will be compared against Pesaran et al. (2001) upper and lower critical values. The null hypothesis for this test is there is no cointegration; if the F-statistics is higher than the upper critical value, the null hypothesis will be rejected concluding that the variables move together in long run. If the F-statistics is below the lower critical value, the null hypothesis is accepted concluding no variables move together in long run. Conditions where F-statistics falls between the lower and up critical values gives an inconclusive result meaning there might be cointegration or there might not be cointegration.

VECM

Vector Error Correction Model (VECM) uses the estimated error term to specify which variable is endogenous and exogenous. The variable is endogenous when the error correction term is significant while if the error correction term is insignificant, the variable is specified as exogenous. The speed of adjustment towards equilibrium depends on the coefficient of the error term. A positive sign shows that the variable will move away from equilibrium while a negative sign will show the movement of variable towards equilibrium. The speed is determined by the absolute value of the error term; closer to one signal fast speed of adjustment while closer to zero signals slow speed of adjustment.

NARDL

The weakness of ARDL is the assumption of symmetric adjustment and linearity. When a variable decrease and increases at the same speed, the variable is said to be symmetric while linearity means any proportionate change in the endogenous variable will lead to change in the dependent variable. Nonlinear Autoregressive Distributed Lag (NARDL) is a technique relaxing the ARDL assumptions and identifies the short-run long-run relationships when the relationships are non-linear and asymmetric. There are many advantages using NARDL, first it does not assume symmetric and linearity, the cointegration tested would be linear and non-linear while separating the long-run short-run regressors to the endogenous variable. From NARDL technique, the researcher can find out the NARDL model is correct or the ARDL is correct by looking at the result of the NARDL test. If the NARDL model is rejected, there is a symmetric relationship and ARDL model is correct.

VDC

In the error correction model, the result specified which variables are exogenous and endogenous. However, it did not specifically show the degree of exogeneity and endogeneity between the variables. Variance Decomposition (VDC) will explain the degree of exogeneity or endogeneity of the variables by looking at the proportion of the variance explained by its own past. A variable that can explain its own self the most is the most exogenous while the least is endogenous. VDC can be performed in two ways, generalized and orthogonalized. Generalised VDC does not depend on the ordering of the VAR and assumes not all variables are switched off when a variable is shocked .Orthogonalised VDC depends on the ordering of the VAR and assumes that the system is switched off when a variable is shocked. The next step is to apply Impulse Response Function to see the effects of other variables when a specific variable is shocked. The last step is Persistence Profile (PP) which uses system wide shock technique to see how long the system will come back to equilibrium.

Empirical Results

Unit Root Test

	VARIABLE	ADF	VALUE	T-STAT.	C.V.	RESULT
LOG FORM	LGFCF	ADF(1)=AIC	35.7706	-0.2810	-3.5273	non-stationary
		ADF(1)=SBC	32.5488	-2.8101	-3.5273	non-stationary
	LGFCFP	ADF(1)=AIC	23.8975	-2.9504	-3.5273	non-stationary
		ADF(1)=SBC	20.6756	-2.9504	-3.5273	non-stationary
	LCPI	ADF(1)=SBC	-33.6431	-2.9919	-3.5273	non-stationary
		ADF(3)=AIC	-29.0094	-4.0157	-3.5242	stationary
	LREV	ADF(1)=SBC	50.6281	-2.7800	-3.5273	non-stationary
		ADF(2)=AIC	53.8660	-3.0980	-3.5314	non-stationary
	LEMP	ADF(1)=SBC	108.0959	-2.6930	-3.5273	non-stationary
		ADF(2)=AIC	111.5173	-3.0823	-3.5314	non-stationary
	LGDP	ADF(1)=SBC	31.5857	-2.3891	-3.5273	non-stationary
		ADF(3)=AIC	34.9124	-2.7971	-3.5242	non-stationary
	LTO	ADF(1)=SBC	38.5226	-1.0759	-3.5273	non-stationary
		ADF(1)=AIC	41.7445	-1.0759	-3.5273	non-stationary
1ST DIFF. FORM	VARIABLE	ADF	VALUE	T-STAT.	C.V.	RESULT
	DGFCF	ADF(1)=SBC	29.2720	-4.2610	-3.4717	stationary
		ADF(1)=AIC	32.4390	-4.2610	-3.4717	stationary
	DGFCFP	ADF(1)=SBC	17.5128	-4.2630	-3.4717	stationary
		ADF(1)=AIC	20.6798	-4.2630	-3.4717	stationary
	DCPI	ADF(1)=SBC	-36.6280	-5.3127	-3.4717	stationary
		ADF(4)=AIC	31.1065	5.2085	-3.5949	stationary
	DREV	ADF(1)=SBC	45.3012	-4.1366	-3.4717	stationary
		ADF(1)=AIC	48.4682	-4.1366	-3.4717	stationary
	DEMP	ADF(1)=SBC	101.2573	-4.1354	-3.4717	stationary
		ADF(3)=AIC	104.8092	-4.3366	-3.5274	stationary
	DGDP	ADF(1)=SBC	27.7883	-3.5872	-3.4717	stationary
		ADF(1)=AIC	30.9553	-3.5872	-3.4717	stationary
	DTO	ADF(1)=SBC	36.5248	-4.5143	-3.4717	stationary

		ADF(1)=AIC	39.6918	-4.5143	-3.4717	stationary

Table2: ADF test for log form and first difference

	Variable	Value	C.V	Result
LOG FORM	LCPI	-5.5351	-3.4806	stationary
	LEMP	-2.5326	-3.4806	non-stationary
	LGDP	-1.3467	-3.4806	non-stationary
	LGFCF	-1.5626	-3.4806	non-stationary
	LGFCFP	-1.5387	-3.4806	non-stationary
	LREV	-2.2886	-3.4806	non-stationary
	LTO	-1.0639	-2.8818	non-stationary
1st Difference FORM	Variable	Value	C.V	Result
	DCPI	-15.5267	-2.9324	stationary
	DEMP	-9.0476	-2.9324	stationary
	DGDP	-3.3899	-2.9324	stationary
	DGFCF	-3.7543	-2.9324	stationary
	DGFCFP	-3.6893	-2.9324	stationary
	DREV	-8.3012	-2.9324	stationary
	DLTO	-6.4228	-2.9324	stationary

Table 3: PP test for log form and first difference

The ADF test result on Table 2 shows that all variables are non-stationary it its log level from except for LCPI which is stationary after taking the log from. All the variables in the first difference from in ADF test are stationary. LCPI is also stationary in PP test after taking log from while the rest is non-stationary and the first difference from for all the variables are stationary. CPI will be a problem when testing for cointegration test for Engle Granger and Johansen as it requires variables to be in non-stationary from however, we can apply ARDL test as it does no require non-stationary assumption. This paper will not apply KPSS because KPSS does not take care of autocorrelation and heteroscedasticity problem.

Cointegration test: ARDL

Variable	F-statistics	p-value	Critical Lower Bound	Critical Upper Bound	Conclusion
DGDP	7.2019	0.127	2.752	3.882	cointegration
DCPI	1.5043	456	2.752	3.882	no cointegration
DGFCF	0.73041	0.685	2.752	3.882	no cointegration
DGFCFP	1.2281	0.519	2.752	3.882	no cointegration
DTO	1.0382	0.573	2.752	3.882	no cointegration
DREV	0.69359	0.701	2.752	3.882	no cointegration
DEMP	0.56643	0.761	2.752	3.882	no cointegration

Table 4: ARDL Cointegration

From the result of ARDL test on Table 4, there is one cointegration as the F-statistics for GDP shows a value of 7.2019 which above the critical upper bound of value 3.882. When the F-statistics is above the critical upper bound, we can reject the null hypothesis and there is a long run relationship between GDP, inflation, gross fixed capital formation, gross fixed capital formation for private sector, trade openness, revenue and employment which is not spurious when GDP is the dependent variable. There is no long run relationship when inflation, gross

fixed capital formation, gross fixed capital formation for private sector, trade openness, revenue and employment are the dependent variables. With the presence of cointegration, the research can continue to VECM and VDC to identify which variables are endogenous and exogenous followed by the degree of endogenous and exogenous in VDC.

Long Run Structural Model

VRBL	PANEL A
LCPI	0.06212
	-0.02106
LEMP	-26.58290
	-4.27540
LGDP	0.07310
	-0.03394
LGFCF	1.00000
	(*NONE*)
LGFCFP	-0.85492
	-0.03927
LREV	-4.80990
	-0.78609
LTO	0.63535
	-0.10312
Trend	-0.16439
	-0.00731
CHSQ(1)	NONE

Table 5: LRSM test

The LRSM test the coefficient against its theoretical expected value. The result in Table 5 shows that we normalize gross fixed capital formation as it is our focus variable and check for the significance of other variables for exact identification (PANEL A). The result showed that all the

variables are significant. This study didn't proceed to over identification because the study is interested in the lead lag relationship which will be tested in VDC.

Vector Error Correction Model(VECM)

ecm1(-1)	**Coefficient**	**Standard Error**	**T-Ratio [Prob.]**	**C.V.**	**Result**
dLCPI	-5.3758	3.7604	-1.4296[.172]	5%	exogenous
dLEMP	.086755	.060430	1.4356[.170]	5%	exogenous
dLGDP	-1.2303	.46885	-2.6241[.018]	5%	endogenous
dLGFCF	-.71876	.4630	-1.5504[.141]	5%	exogenous
dLGFCFP	-1.1128	0.60321	-1.8448[.084]	5%	exogenous
dLREV	-0.35077	0.29345	-1.1953[.249]	5%	exogenous
dLTO	-1.1197	0.38096	-2.9292[.010]	5%	endogenous

Table 6: Error Correction Model

VECM test specifies which variable is endogenous or exogenous by looking at the p-value, if the p-value is less than 5 % the variable is endogenous. The result from Table 6 shows that trade openness and GDP is the only endogenous variable while inflation, employment, gross fixed capital formation, gross fixed capital formation private sector and revenue are all exogenous variable. Policy makers can predict trade openness by looking at inflation, employment, gross fixed capital formation, gross fixed capital formation private sector and revenue. As GDP is endogenous, we can intuitively say that other variables can give an impact to GDP as for

example trade openness and revenue. Both gross fixed capital formation in public and private sectors is exogenous because there are many external factors that cause public and private firms to invest; economic activity and global economy can impact these investment variables. Revenue is also exogenous because the revenue depends of economic activity, if the economy is active then there are lots of transactions and goods and services which can be captured in government revenue. Employment is another exogenous variable because it depends on the economic activity hence it can be related to gross fixed capital formation because if there is no investment due to poor economic condition, there will be no job creation. If GDP is falling, the government can control inflation rate by applying tight fiscal policy as to increase income tax or lower government expenditure will decrease aggregate demand therefore lowering growth and less demand-pull inflation. Monetary policy can be applied to enhance economic growth which can lead to trade openness with lower inflation and lower interest rate.

The coefficients of the variables in the error correction model can determine how long will the variables will return to long run equilibrium. A negative sign determines a movement of variables towards long run equilibrium while a positive sign indicates a movement away from long run equilibrium. From the result in table 5, only employment contain a positive sign while gross fixed capital formation for public and private, inflation, trade openness and GDP have a negative sign indicating variables moving towards from long run equilibrium.

Variance Decomposition (VDC)

NORMALISED								
Horizon	Variable	LCPI	LEMP	LGDP	LGFCF	LGFCFP	LREV	LTO
10	LCPI	19.7290%	14.2540%	13.5134%	5.5399%	22.9095%	6.0323%	18.0218%
10	LEMP	7.2914%	17.5860%	15.8376%	26.9928%	2.7120%	24.6563%	4.9238%
10	LGDP	11.6348%	4.7118%	4.7339%	13.9725%	9.8850%	17.2804%	37.7815%
10	LGFCF	12.3806%	19.2831%	19.0310%	12.0218%	5.3889%	12.3067%	19.5880%
10	LGFCFP	12.9145%	16.8922%	18.8518%	14.3189%	6.2630%	14.9839%	15.7758%
10	LREV	6.7117%	18.0207%	15.3821%	28.2151%	2.3903%	25.1126%	4.1675%
10	LTO	31.8603%	17.3792%	20.2336%	3.2961%	21.2035%	3.6250%	2.4023%
	Exogeneity	19.7290%	17.5860%	4.7339%	12.0218%	6.2630%	25.1126%	2.4023%
	Ranking	2	3	6	4	5	1	7

Table 7: Normalised VDC at 10 Horizons

NORMALISED								
Horizon	Variable	LCPI	LEMP	LGDP	LGFCF	LGFCFP	LREV	LTO
20	LCPI	21.1908%	14.9261%	14.5024%	3.5224%	25.6296%	3.9229%	16.3058%
20	LEMP	6.8308%	17.8859%	15.8635%	27.6700%	1.9868%	25.0158%	4.7471%
20	LGDP	8.9414%	8.6106%	6.9067%	11.7793%	8.7767%	13.9564%	41.0289%
20	LGFCF	9.2229%	23.7917%	22.0093%	14.7441%	3.2128%	13.7539%	13.2652%
20	LGFCFP	10.6890%	20.6901%	22.9524%	15.1628%	4.1773%	14.7338%	11.5945%
20	LREV	6.4613%	18.5654%	15.4924%	28.5942%	1.7572%	25.3985%	3.7309%
20	LTO	31.3918%	18.5967%	21.0147%	3.8792%	19.1411%	4.1389%	1.8377%
	Exogeneity	21.1908%	17.8859%	6.9067%	14.7441%	4.1773%	25.3985%	1.8377%
	Ranking	2	3	5	4	6	1	7

Table 8: Normalised VDC at 20 Horizons

NORMALISED								
Horizon	Variable	LCPI	LEMP	LGDP	LGFCF	LGFCFP	LREV	LTO
30	LCPI	22.3713%	15.5024%	15.1884%	2.9098%	25.7861%	3.3017%	14.9404%
30	LEMP	6.2612%	18.0719%	15.8049%	28.1654%	1.8442%	25.3289%	4.5234%
30	LGDP	7.2923%	9.6493%	7.2673%	9.6328%	7.9371%	11.4200%	46.8012%
30	LGFCF	7.5398%	25.7814%	23.1916%	15.5379%	2.2793%	13.9414%	11.7286%
30	LGFCFP	9.0350%	22.9108%	25.0341%	15.6810%	3.0928%	14.5697%	9.6767%
30	LREV	6.0113%	18.8036%	15.4487%	28.9634%	1.6473%	25.6713%	3.4544%
30	LTO	31.2152%	19.0676%	21.2916%	4.2051%	18.1799%	4.4423%	1.5985%
	Exogeneity	22.3713%	18.0719%	7.2673%	15.5379%	3.0928%	25.6713%	1.5985%
	Ranking	2	3	5	4	6	1	7

Table 9: Normalised VDC at 30 Horizons

NORMALISED								
Horizon	Variable	LCPI	LEMP	LGDP	LGFCF	LGFCFP	LREV	LTO
40	LCPI	22.7732%	15.8587%	15.5221%	2.7649%	25.4512%	3.1486%	14.4813%
40	LEMP	6.0283%	18.1058%	15.8098%	28.2318%	1.8072%	25.2636%	4.7534%
40	LGDP	6.0834%	9.9067%	7.2941%	8.0563%	7.7082%	9.7417%	51.2096%
40	LGFCF	6.6319%	26.8270%	23.9949%	15.4768%	1.8760%	13.5689%	11.6244%
40	LGFCFP	8.0513%	24.0866%	26.4130%	15.4789%	2.6095%	14.0042%	9.3565%
40	LREV	5.8265%	18.8972%	15.4742%	29.0204%	1.6080%	25.6385%	3.5353%
40	LTO	31.0745%	19.3135%	21.4213%	4.3940%	17.6782%	4.6212%	1.4974%
	Exogeneity	22.7732%	18.1058%	7.2941%	15.4768%	2.6095%	25.6385%	1.4974%
	Ranking	2	3	5	4	6	1	7

Table 10: Normalised VDC at 40 Horizons

Generalized VDC is favoured in this study due to the strength over orthogonalized VDC. Generalized does not require the ordering of VAR and it does not assume when a variable is shocked, all other variables in the system are switched off. The result in Table 10 show normalized VDC after 40 horizons. Picking a lot of period horizons is necessary if the ranking of exogeneity keeps changing horizon to horizon. The ranking compliments the VECM result as trade openness is an endogenous variable and in the VDC, it the least exogenous variable as it has the lowest percentage at explain its own past.

The Figure 1 shows that impact of variable on the other. Trade openness can be used to control revenue and it is the most exogenous. For a government to invest in infrastructure, they need capital and mostly gross fixed capital formation come from the revenue side. The line further shows that private corporation drive the public for infrastructure investment and drives the employment rate. The private investment further shows that it drives the GDP and the GDP will drive the public investment on infrastructure. Figure 2 describes the generalized impulse response function shocking revenue which is the most exogenous variable. CPI is the only variable that the variance is not constant, and the volatility is high. It could be because of the earlier unit root test when test for variable stationarity, CPI stayed stationary after taking the log form which explains the result.

Figure 1: Left as least exogenous, right as most exogenous

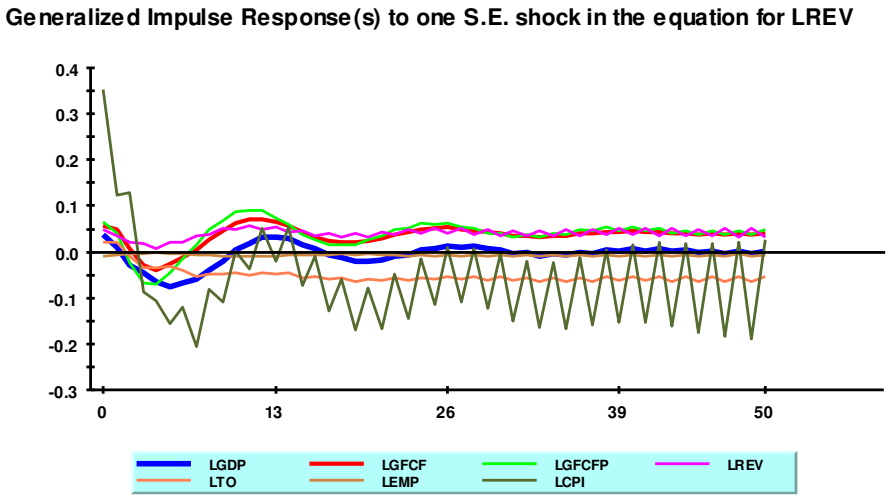

Figure 2: Generalised Impulse Response Function for revenue

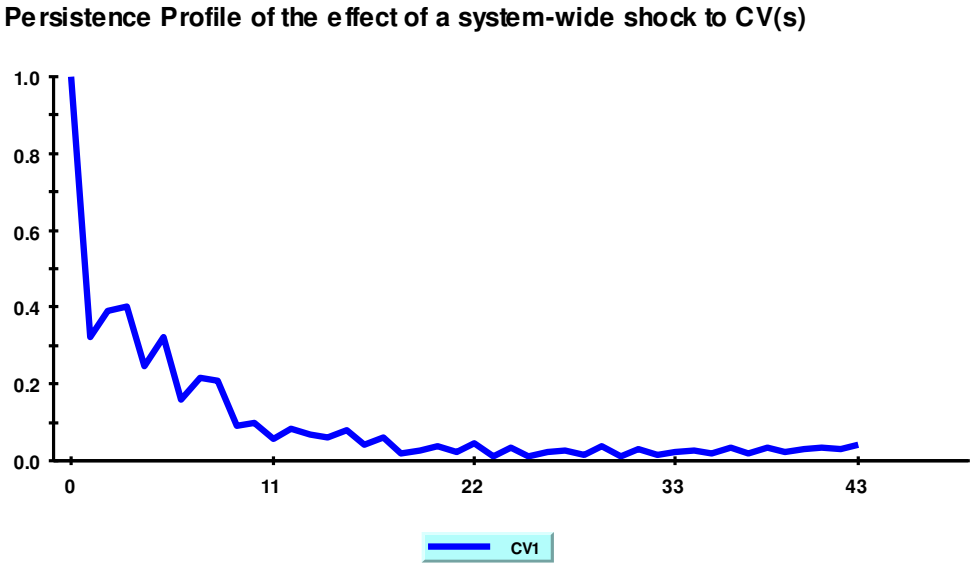

Figure 3: Persistence Profile graph

Persistence Profile is when you apply wide shock to the system and see how long it takes for the system to get back to equilibrium. Based on the result in Figure 3, we can say that it takes just over 22 years just for the system to be stable, however the line is not smooth, and it could be due to the stationarity of CPI that caused the problem.

Nonlinear Autoregressive Distributed Lags (NARDL)

The focus on this study are the two variables, gross fixed capital formation and GDP as the study wants to see infrastructure investment on economic growth. NARDL will test whether there is long run relationship between the two variables and is it linear or nonlinear relationship.

Independent Variable: GDP	F-statistics	p-value	Selected Specification
Long Run	115.3	0.00	Asymmetric
Short Run	4.757	0.095	Asymmetric

Table 11: Wald Test

The result from in Table 11 shows there is asymmetric relationship between the two variables in the short run and the long run. This study can use both model of ARDL and NARDL therefore there could be asymmetric relationship and symmetric between the focus variables.

Conclusion and Policy Implications

It is usually recognized that public infrastructure is an important ingredient for economic growth.. What is not clear, however, is the leader-follower relationship between them. This paper is focused on whether the infrastructure leads GDP or the other way around. Thailand is used as a case study. The methods used are the ARDL and nonlinear ARDL. The nonlinear ARDL analysis indicates that the cointegrating relationship between the two variables is nonlinear and that the relationship is asymmetric in both the short and long run. Furthermore, the findings based on variance decomposition analysis tend to indicate that infrastructure drives GDP and not the other way around. These findings appear to be intuitive and contain strong policy implications for the decision makers in an emerging economy like Thailand.

Limitations of this paper includes the use of data type. Macroeconomic variables used in this study are annual data and if the study had monthly data, it would take a step deeper into the variables and we might capture a different interpretation. Another limitation is the variable CPI which is in stationary form after taking log therefore the study could not conduct Engle-Granger and Johansen cointegration test. Lastly, there might be other variables that have been omitted

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