Nexus of infrastructure investment, economic growth and domestic credit level: evidence from China based on nonlinear ARDL approach

Zichu, Jin and Masih, Mansur

INCEIF, Malaysia, Business School, Universiti Kuala Lumpur, Kuala Lumpur, Malaysia

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Jin Zichu[1] and Mansur Masih[2]

Abstract:

Infrastructure has experienced a rapid development in China over the past decade. The economic contribution of infrastructure investment has been widely examined in the literature using various data and models. However, the results are inconclusive. This paper using Nonlinear ARDL tests the effect of infrastructure investment on both GDP and domestic private credit level. The paper finds that an increase in infrastructure investment will increase GDP but push the domestic credit level higher. The contribution of this paper is that a stable investment in infrastructure is needed, while the efficiency of the management is also important. Government should take care of the debt level and reduce the debt leverage, as more debt will eventually drag the economy down.

Keywords: Infrastructure, GDP, domestic credit, NARDL, China

[1] INCEIF, Lorong Universiti A, 59100 Kuala Lumpur, Malaysia.

2 **Corresponding author**, Senior Professor, UniKL Business School, 50300, Kuala Lumpur, Malaysia.

Email: mansurmasih@unikl.edu.my

1. Introduction

Theoretically, the Infrastructure investments increase output in the short-term by boosting aggregate demand. And Infrastructure investments increase output in the long-term by boosting aggregate supply. However, a debt based infrastructure financing may cause burden in both public and private sector, thus slow down the economy. Ansar, et al. (2016) found that if investments are debt-financed, overinvesting in unproductive projects results in the build-up of debt, monetary expansion, instability in financial markets, and economic fragility, exactly as we see in China today. Tsui (2011) found the investment boom in infrastructure sector is also fostered by the debt-laden which has drawn local governments into a land-infrastructure leverage trap in China.

Existing studies that examine the relationship is mainly based on the contribution of infrastructure development and GDP relations, while the impact on the domestic private credit level has less attention, especially the non-linear effect in the short-run and long run.

It is important to know the causal relationship among variables for a better justification. Meanwhile, taking asymmetric effect in the short run and long run into account is important because a positive or negative variation on one variable does not have the same impact on the other variable. Therefore, in the economic system with full of complexity, asymmetry in the infrastructure investment and economic impact (in GDP per capita level and domestic private credit level) relationships may appear different to changes during boom and recession among different sectors. This phenomenon possibly implies that linear models may not be appropriate or adequate enough to explore the infrastructure development in different sectors. As the intention of this research is to examine the long run relationship and the asymmetric effects between three selected infrastructure sectors effect to the GDP and the Domestic Credit (Ismail, N. W., and J. M. Mahyideen. 2015). Results demonstrate that improvements in transport infrastructure (i.e., the road density network, air transport, railways, ports, and logistics) have resulted in increased business activities to economic growth.

This study contributes to current non-linear ARDL literature. And an empirical study is used to find out the relationship of the infrastructure investment and the economic growth, infrastructure investment to the domestic private credit level.

The following is the structure of the paper: section 2 literature review of the existing study related to this topic. Section 3 explains the methodology and data sources. Section 4 presents the empirical findings and discussion. Section 5 is the conclusion.

2. Literature review

Infrastructure drives demand and escorts economic growth. On the one hand, infrastructure investment can boost economic demand; on the other hand, infrastructure improvements contribute to long-term economic development. For China, infrastructure investment has always been one of the main drivers of economic growth. Since 2012, the growth rate of China's infrastructure investment has been maintained at around 20%, and the proportion of fixed assets investment has also reached 25% in 2016.

The empirical approaches has been used in the growth regressions augmented with infrastructure measures where majority of studies especially recent ones on developing economies find significant positive effects between these two variables.

Démurger (2001) provides empirical evidence on the links between infrastructure investment and economic growth in China. The estimation of a growth model shows that, besides differences in terms of reforms and openness, geographical location and infrastructure endowment did account significantly for observed differences in growth performance across provinces. The results indicate that transport facilities are a key differentiating factor in explaining the growth gap. Meanwhile, Esfahani & Ramírez (2003) develops a structural model of infrastructure and output growth found cross-country estimates of the model indicate that the contribution of infrastructure services to GDP is substantial. Liu & Hu (2010) indicate that transport infrastructure has a significant positive impact on China’s economic growth; Different geography and transport infrastructure condition plays important roles in regional disparities.

Canning & Pedroni (2008) show that while infrastructure does tend to cause long-run economic growth, there is substantial variation across countries. Canning, D., & Pedroni, P. (2004) investigate the long run consequences of infrastructure provision on per capita income. Simple tests are devised for the existence and sign of the long run impact of infrastructure on income allowing for non-stationarity and cointegration in the time series, and heterogeneity in both the short run and long run responses across countries. The findings indicate a great deal of heterogeneity across countries. Researches have also conducted in the infrastructure development to the regional economic growth effect, such as Hong, Chu & Wang (2011) land transport infrastructure contributes more to economic growth in locations with poor land transport infrastructure. And Beyzatlar, & Kuştepeli (2011) estimated both tangible and intangible effects of railway infrastructure. The cointegration and causality tests results imply that there is a positive long run relationship between railway length and population density and between railway length and real GDP per capita. He found that railway length causes real GDP per capita to increase only in the long run but it causes population density to increase both in the long and the short run.

Calderón and Servén (2008) assessed the effects of infrastructure on economic growth and inequality with a specific focus on Sub-Saharan Africa. They demonstrated that an increase in the volume of infrastructure stocks and improved infrastructure quality had a positive impact on long-run growth and a negative impact on income inequality.

Based on causality study Sahoo & Nataraj (2010) investigated the role of infrastructure in promoting economic growth in China for the period 1975 to 2007. Overall, the results reveal that infrastructure stock, labour force, public and private investments have played an important role in economic growth in China. More importantly, the finding shows Infrastructure development in China has significant positive contribution to growth than both private and public investment. Further, there is unidirectional causality from infrastructure development to output growth justifying China's high spending on infrastructure development since the early nineties. The experience from China suggests that it is necessary to design an economic policy that improves the physical infrastructure as well as human capital formation for sustainable economic growth in developing countries.

Study has also shown a bilateral effect in economic growth and infrastructure investment. Hong (2004) found that the investment in infrastructure can be both of exogenous and endogenous. This paper reached the following conclusion: when the exogenous infrastructure is of pure public, it can generate long run and sustainable growth rate. And when the infrastructure is of congestion it can also increase the long run growth rate. If the endogenous infrastructure is of pure public, it can lead to constant endogenous growth and if the infrastructure is of congestion, it can also increase the long run growth rate which varies according to the degree of congestion. Pradhan & Bagchi (2013) examines the effect of transportation (road and rail) infrastructure on economic growth in India over the period 1970–2010. Using Vector Error Correction Model (VECM), the paper finds bidirectional causality between road transportation and capital formation, bidirectional causality between gross domestic capital formation and economic growth, unidirectional causality from rail transportation to economic growth and unidirectional causality from rail transportation to gross capital formation. The paper suggests that expansion of transport infrastructure (both road and rail) along with gross capital formation will lead to substantial growth of the Indian economy.

3. Data and methodology:

Following the existing empirical literature in this area, this research uses 5 variables in the first part of empirical study. The main variables are economic growth, domestic private credit level and infrastructure investment. While two control variables CPI and energy consumption. Below is the summary of the selected variables.

Variables	Description	Source
GDP Per capita	Gross Domestic Product divided by Total Population	World bank
CPI	CPI (Customer Price Index)	National Bureau of Statistics of China
K	Gross fixed capital formation (current LCU)	World bank
DC	Domestic credit to private sector	World bank
EC	KG of oil equivalent per capita	World bank
Sectors		
EI	**Energy Infrastructure sector** Pipeline oil (gas) mileage (km) And National Railway Electrification Mileage (km)	National Bureau of Statistics of China
Road	**Transportation infrastructure sector** Highway mileage km) Railway mileage (km)	National Bureau of Statistics of China
Air	**Air infrastructure sector** Regular flight route mileage (km) International route length (km)	National Bureau of Statistics of China

GDP per capita represents economic growth. Real domestic private credit to the private sector per capita is a measure of the Domestic private credit level. Real gross fixed capital formation per capita is a proxy for total Infrastructure investment. CPI is a proxy of inflation so that Positive impact of GDP per capita can be explained, as controlled inflation can stimulate the economy, however, the persistence of high inflation in the long-run can be harmful for the economy.

The amount of investment to the infrastructure data in different sectors is not readily available for China. The usage adjustment factor is a crude proxy based on the assumption that each sector with the physical development, for example, road length and road transportation carried can be observed in proportion to its contribution to impact in the economy. Following Calderón and Chong (2009) and Sahoo et al. (2010), the indicators used to represent infrastructure measures for the transport sector is the length of the total roads. Here, based on the data available it is the combine of total highway mileage (km) and railway (km). Pipeline oil (gas) (km) together with national Railway Electrification (km) are used as the proxy of the energy infrastructure investment sector. Meanwhile, a regular flight route mileage (km) plus international route length (km) in China is used as the proxy of the total air infrastructure investment.

We transformed all the variables into per capita units by dividing them by the total population for each year. To increase the accuracy of our empirical results, quarterly frequency data are used for the period from 1977Q1-2017Q4. For this purpose, we employed the quadratic match-sum method to transform the annual frequency data into quarterly frequency data, following Sbia et al. (2014), Shahbaz, et al. (2017), Borjigin, et al (2018). As in theory, the multiple economic series data are with a trend, as such the time series are non-stationary in their original level form. If the variables are non-stationary, the conventional statistical tests are not valid. Normally the real time data do has a seasonal effect, known as the data movements is with a business cycle. De-seasonalize all economic series is a necessary step to analyse the trend from the data, and it will allow as to see a clearer patterns of the trend. By use quadratic match sum method which fits a local quadratic polynomial for each observation of the original yearly series, using the fitted polynomial to fill in all observations of the higher frequency, quarterly series associated with the period. The quadratic polynomial is formed by taking sets of three adjacent points from the original series and fitting a quadratic so that the sum of the interpolated quarterly data points matches the actual yearly data points. It helps to increase sample observations by keeping original trend sustainably at the same time solving the problem related to the seasonal variation. Chen et al. (2012) also reported that seasonality problem can be avoided by applying the quadratic match-sum approach, as this method minimizes the point-to-point data variations.

Table 1: summary of variables.

	GDP	DC	K	CPI	EC	AIR	ROAD	EN
Max	4.161	3.938	3.811	2.205	2.835	6.452	6.090	4.602
Min	2.712	1.324	1.336	1.393	2.141	4.591	5.343	3.238
Std.	0.435	0.778	0.780	0.281	0.211	0.497	0.270	0.389
Skew	0.038	-0.372	-0.052	-0.521	0.612	-0.166	0.554	0.131
Kurt	1.758	1.928	1.664	1.676	1.901	1.919	1.598	1.848
JB	10.580	11.631	12.266	19.397	18.503	8.740	21.814	9.541
Prob	0.005	0.003	0.002	0.000	0.000	0.013	0.000	0.008
Obs	164	164	164	164	164	164	164	164

The statistics summary in Table 1, Jarque-Bera statistics reveal the non-normal distribution of the series. These characteristics of the series show the necessity of relying on asymmetric methods, as we do in this study.

Before we conduct further analysis, the common practice is to use the augmented Dicky-Fuller (ADF) test. The order of integration in our series is investigated using three standard unit root tests: Augmented Dickey-Fuller-GLS, Phillips-Perron test and Kwiatkowski et al. (KPSS). The

ADF-GLS test and Phillips-Perron test is based on the null hypothesis of a unit root, while the KPSS test considers the null of no unit root.

From Table 2, ADF shows that the null hypothesis of a unit root cannot be rejected for all variables at log-form, indicating that they are nonstationary. However, with the first-differences, EC statistics cannot reject the null hypothesis, thus there is a unit root. In Table 3, PP test is conducted and found all variables are stationary in I(1). PP test as compare to ADF test take care both autocorrelation and heteroscedasticity problem by using Newey-West adjusted-variance method, the result of it is more robust. Thus, we decide all variables are I(1).

Table 2: ADF test for log-form and first-differenced form

	VARIABLE	ADF	T-STAT.	C.V.	RESULT
LOG FORM	LGDP	ADF(2)=SBC	- 3.387	- 3.456	Non-Stationary
		ADF(5)=AIC	- 3.549	- 3.398	Stationary
	LCPI	ADF(2)=SBC	- 1.624	- 3.490	Non-Stationary
		ADF(5)=AIC	- 1.100	- 3.472	Non-Stationary
	LDC	ADF(5)=SBC	- 1.188	- 3.398	Non-Stationary
		ADF(5)=AIC	- 1.188	- 3.398	Non-Stationary
	LK	ADF(1)=SBC	- 3.253	- 3.398	Non-Stationary
		ADF(1)=AIC	- 3.253	- 3.398	Non-Stationary
	LEC	ADF(5)=SBC	- 2.075	- 3.398	Non-Stationary
		ADF(5)=AIC	- 2.075	- 3.398	Non-Stationary

	VARIABLE	ADF	T-STAT.	C.V.	RESULT
1ST DIFF. FORM	DGDP	ADF(0)=SBC	- 3.8442	- 2.8475	Stationary
		ADF(3)=AIC	- 3.9921	- 2.8934	Stationary
	DDC	ADF(3)=SBC	- 6.7918	- 2.8934	Stationary
		ADF(4)=AIC	- 4.4051	- 2.8574	Stationary
	DCPI	ADF(0)=SBC	- 3.5779	- 2.8475	Stationary
		ADF(3)=AIC	- 3.5246	- 2.8934	Stationary
	DK	ADF(4)=SBC	- 3.3924	- 2.8574	Stationary
		ADF(4)=AIC	- 3.3924	- 2.8574	Stationary
	DEC	ADF(4)=SBC	- 2.6756	- 2.8574	Non-Stationary
		ADF(4)=AIC	- 2.6756	- 2.8574	Non-Stationary

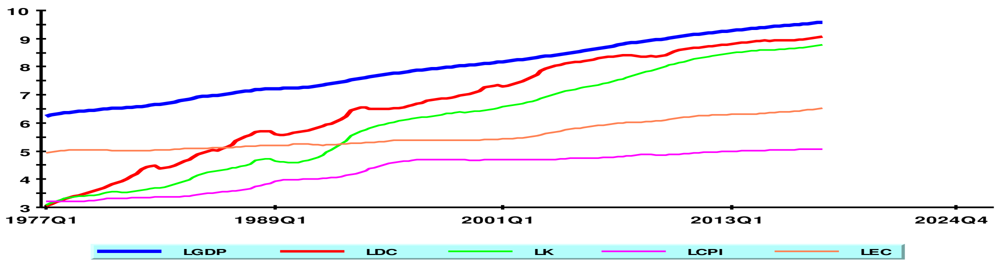
Table 3: PP test for log-form and first differenced form

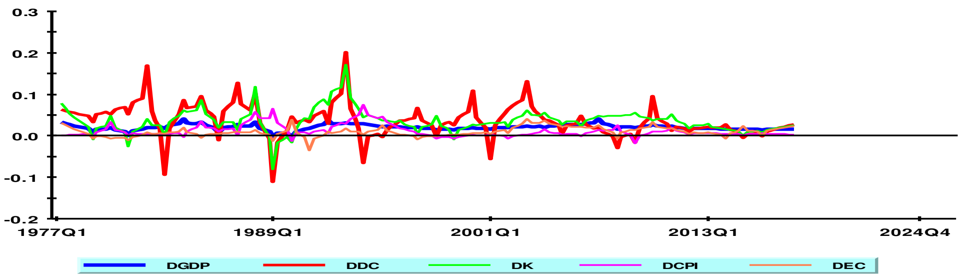
	VARIABLE	T-STAT.	C.V.	RESULT		VARIABLE	T-STAT.	C.V.	RESULT
LOG FORM	LGDP	-1.9478	-3.4301	Non-Stationary	1ST DIFF. FORM	DGDP	-3.7787	-2.8934	Stationary
	LDC	-0.54441	-3.4301	Non-Stationary		DDC	-5.9368	-2.8934	Stationary
	LK	-1.5138	-3.4301	Non-Stationary		DK	-4.2427	-2.8934	Stationary
	LCPI	-0.85352	-3.4301	Non-Stationary		DI	-3.5792	-2.8934	Stationary
	LE	-1.0224	-3.4301	Non-Stationary		DE	-5.1337	-2.8934	Stationary

Table 4: KPSS test for log-form and first differenced form

	VARIABLE	T-STAT.	C.V.	RESULT		VARIABLE	T-STAT.	C.V.	RESULT
1ST DIFF. FORM	LGDP	0.10563	0.13668	Stationary	1ST DIFF. FORM	DGDP	0.08878	0.39145	Stationary
	LDC	0.1827	0.13668	Non-Stationary		DDC	0.55327	0.39145	Non-Stationary
	LK	0.090169	0.13668	Stationary		DK	0.13173	0.39145	Stationary
	LCPI	0.16128	0.13668	Stationary		DI	0.22023	0.39145	Stationary
	LE	0.1776	0.13668	Non-Stationary		DE	0.35104	0.39145	Stationary

Figure 1 shows the tested variables, the first differenced forms are expected to be stationary.





Next, we find the order of vector autoregression. In Table 5, AIC gives 2 lags, SBC gives 2 lags and adjusted LR test gives 5 lags. We will choose 5 lags suggested by LR test.

Table 5: Order of vector autoregression

Order	LL	AIC	SBC	LR test	Adjusted LR tes
5	2775.3	2650.3	2458.5	.	
4	2692.6	2592.6	2439.2	CHSQ(25)= 165.4392[.000]	139.4268[.000]
3	2687.2	2612.2	2497.1	CHSQ(50)= 176.3185[.000]	148.5954[.000]
2	2668.3	2618.3	2541.6	CHSQ(75)= 214.0513[.000]	180.3954[.000]
1	2337.9	2312.9	2274.5	CHSQ(100)= 874.8411[.000]	737.2875[.000]
0	-512.9855	-512.9855	-512.9855	CHSQ(125)= 6576.6[.000]	5542.6[.000]

Johansen's cointegration test. In Table 6, the null hypothesis of no cointegration is rejected at 5% significant level based on Maximal Eigenvalue. Based on Traces, the null hypothesis of two cointegration against alternative hypothesis of three cointegration could not be rejected at 5% significant level.

Table 6: cointegration test based on maximal eigenvalue and trace of the Stochastic matrix

Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix					
Null	Alternative	Statistic	95% Critical Value	90% Critical Value	Result
r = 0	r = 1	57.66	37.07	34.16	2
r<= 1	r = 2	34.73	31.00	28.32	Cointegration
r<= 2	r = 3	17.13	24.35	22.26	
Cointegration LR Test Based on Trace of the Stochastic Matrix					
Null	Alternative	Statistic	95% Critical Value	90% Critical Value	Result
r = 0	r>= 1	116.38	82.23	77.55	1
r<= 1	r>= 2	58.72	58.93	55.01	Cointegration

Johansen cointegration test has limitation as this test assumes that all variables are I(1). Moreover, it is sensitive to number of lags in the order of VAR. Changing number of lags will give different result. In addition, stationary test is biased as the test tend to accept the null at 95% of the time. Stationary test could be sensitive to whether trend term is presence or intercept is presence. Therefore, we will perform ARDL as this test could be applied with both I(1) and I(0) and bypass many limitations.

4. Autoregressive distributed lags (ARDL)

ARDL model was introduced by Pesaran et al. (2001) in order to incorporate I(0) and I(1) variables in same estimation, so if our variables are stationary I(0) then OLS is appropriate and if all are non stationary I(1) then it is advisable to do VECM (Johansen Approach) as it is much simple model.

The ARDL technique involves two stages. At the *first* stage, the existence of a long-run relationship among the variables is investigated. This is done by constructing an unrestricted error correction model (UECM) with each variable in turn as a dependent variable and then testing whether or not the 'lagged levels of the variables' in each of the error correction equations are statistically significant (i.e., whether the null of 'no long run relationship' is accepted or rejected).

Table 7, we test for long-run relationship and found that F-statistics in China GDP and domestic private credit level income are higher than upper critical bound. Thus, we reject the null hypothesis of no long-run relationship and conclude that there is a cointegration among the selected variables.

Table 7: Tests of long-run relationship in ARDL

Model	F-statistic	Critical value bound F statistic (95%)	
GDP (GDP, DC, K, EC, CPI)	F(5,133)= 6.9011[.000]	I(0)	I(1)
DC (GDP, DC, K, EC, CPI)	F(5,133)= 6.6142[.000]	3.189	4.329
K (GDP, DC, K, EC, CPI)	F(5,133)= 3.0425[.012]		
CPI (GDP, DC, K, EC, CPI)	F(5,133)= 1.6644[.148]		

EC (GDP, DC, K, EC, CPI)	F(5,133)= 3.3769[.007]

In Table 8 long-run coefficient of ARDL are estimated using the Akaike Information Criterion. All variables has long run effect to GDP. Variables and K DC is significant at 1% level, and the effect form EC and CPI to GDP is significant at 10% level. This implies that 1% increase in the total infrastructure investment will increase the GDP per capita at 0.36%. Meanwhile, 1% increase in domestic private credit will also increase the GDP by 0.19%. However, inflation will give negative impact to the GDP in the long run. The rise of China's GDP is closely related to the increase in the infrastructure investment and the domestic credit, which indicates the leverage has become higher.

Table 8: long-run coefficients of ARDL

Dependent variable is LGDP

	Coefficient	Standard Error	T-Ratio[Prob]
LK	.36065	.064319	5.6071[.000]
LDC	.19759	.026728	7.3925[.000]
LEC	.19008	.10610	1.7916[.075]
LCPI	-.17610	.090302	-1.9502[.053]
INPT	4.4262	.63495	6.9709[.000]

Cointegration tells us that there is a long-run relationship between variables. However, there could be a short-run deviation from the long-run equilibrium. Cointegration does not tell the process of short-run adjustment to bring about long-run equilibrium. Thus, we will proceed to error-correction model to examine the short-run dynamics.

5. Vector Error Correction Model (VECM)

Table 9, we applied the LRSM for further find the direction of causality among GDP, Domestic Private credit and Infrastructure investment. Where the over-identified Panel B show all the coefficients of the cointegrating vector as highly significant, and the P value 0.929 of which shows a correct restriction. The following analysis will be based on Panel B.

Table 9: Exact and over identifying restrictions on the cointegrating vector

	Panel A		Panel B	
LGDP	1.0000	(*NONE*)	1.0000	(*NONE*)
LDC	-0.081611*	(0.020834)	-0.082577*	0.017674
LK	-0.32674*	(0.053846)	-0.32282*	0.030007
LCPI	0.23019*	(0.065723)	0.22483*	0.024312
LEC	0.00747	(0.08492)	0.00	*NONE*

Log-Likelihood	2780.7		2780.7	
CHSQ(1)			.0078546	[0.929]

Notes: the output above shows the maximum likelihood estimates subject to exactly identifying (Panel A), and over-identifying (Panel B) restrictions. The Panel B estimates show that all the variables are significant (SE are in parenthesis). All the coefficients have the correct signs. The over identification on EC=0 is accepted with a High P-value 0.929. Thus, the result will be proceed with "Panel B" for the remainder of the article.
*Indicated significance at 1% level.

We applied Vector error correction modelling technique. The summary of error correction term for each variable is presented in table 10, it stands for the long-term relationships among variables. The significance to the error correction coefficients shows the variable is endogenous. The finding shows GDP, Domestic Private Credit level and Energy Consumption are endogenous, our main focus variables are in line with the theory. The negative value of the coefficients shows a partial adjustment. The speed of the adjustment can be seen from the absolute value of the coefficient number, Domestic private credit has the highest speed of adjust to back to the equilibrium once shock.

Table 10: Coefficient of error correction term

Dependent variable ECM(-1)

	Coefficient	Standard Error	T-Ratio[Prob]
dLGDP	-.066363	0.013865	-4.7864 [.000]
dLK	-.042606	0.067873	-0.62773[.531]
dLDC	-.27218	0.10110	-2.6921[0.008]
dLCPI	.043520	0.028157	1.5456[.125]
dLEC	-.097064	0.025497	-3.8068[.000]

Orthogonalized Variance decompositions

Generalized Forecast Error Variance							
Relative variance in period 5							
Variables	LGDP	LDC	LK	LCPI	LEC	Self-dep	Rank
LGDP	53.6%	2.7%	35.8%	6.9%	1.0%	53.6%	5
LDC	2.4%	64.3%	25.4%	1.5%	6.4%	64.3%	2
LK	27.1%	9.1%	56.8%	4.9%	2.1%	56.8%	4
LCPI	17.0%	5.6%	14.8%	62.3%	0.2%	62.3%	3
LEC	0.5%	8.6%	6.8%	1.2%	82.9%	82.9%	1
Relative variance in period 10							
Variables	LGDP	LDC	LK	LCPI	LEC	Self-dep	
LGDP	45.8%	2.1%	45.9%	4.8%	1.4%	45.8%	5
LDC	2.9%	60.2%	21.2%	10.0%	5.7%	60.2%	2
LK	28.9%	7.5%	58.8%	3.0%	1.8%	58.8%	3
LCPI	19.4%	10.3%	22.5%	46.9%	0.8%	46.9%	4
LEC	0.4%	9.8%	8.6%	5.0%	76.2%	76.2%	1
Relative variance in period 30							
Variables	LGDP	LDC	LK	LCPI	LEC	Self-dep	
LGDP	15.3%	2.3%	36.6%	44.6%	1.2%	15.3%	5
LDC	14.3%	45.6%	9.2%	27.3%	3.6%	45.6%	3
LK	21.0%	6.5%	62.3%	8.6%	1.7%	62.3%	1
LCPI	22.5%	11.5%	33.4%	31.4%	1.1%	31.4%	4
LEC	3.6%	16.0%	13.3%	18.3%	48.8%	48.8%	2

The VDC decomposes (or partitions) the variance of the forecast error of a particular variable into proportions attributable to shocks (or innovations) in each variable in the system including its own. The relative exogeneity/endogeneity of a variable can be determined by the proportion of the variance explained by its own past shocks. The variable which is explained mostly by its own shocks (and not by others) is deemed to be the most exogenous of all. The result in the Generalized Forecast Error Variance shows that our focus variable GDP is the most the endogenous among the selected variables. domestic private credit and infrastructure investment ranking has changed over the time horizon, as such, in the 30 years longer term, domestic private credit has become the more complicated, and infrastructure investment thus become a relative exogenous variable in which the causality relationship has changed. The instability of it shows the response to the long run and short run asymmetry, and the domestic private credit level become more complex, that need other variables to explain. But since infrastructure investment is our focus variable, it gives us the reference of the leading variable should be domestic credit in the long run in the following tests.

This result give value for the NARDL tests for more detailed in short run and long run asymmetry from different sectors in infrastructure investment to the economic growth and the domestic private credit level.

6. Non-linear autoregressive distributed lags (NARDL)

NARDL can analyze both the long-term and short-term relationships along with the presence of any asymmetry of non-stationary variables in a single equation. Meanwhile, the NARDL model relaxes this restriction and allows for a combination of different integration orders. Thus, it is suitable for exploring and establishing the relationship between the infrastructure investment effect separately to the GDP growth and domestic private credit in China.

We choose to use the multivariate nonlinear ARDL (NARDL) bounds testing approach developed by Shin et al. (2014) because it can capture the nonlinear and asymmetric cointegration between variables. Since NARDL gives more robust results than ARDL, we apply NARDL to three sectors in this section but not apply ARDL to these sectors. NARDL is the main focus of our paper. A clear asymmetric relationship of infrastructure investment (independent variable) to GDP and domestic private credit will be tested respectively. This could give us a clearer picture of the relationship.

NARDL model enables the investigation of the short-run and long-run relationship when these linkages are non-linear and asymmetric. The two equations are shown below, where $\Delta Infra_{t-1}^{+}$

and $\Delta Infra_{t-1}^{-}$ indicate the short run positive and negative impact to the GDP and to Domestic Private Credit level in the second equation.

$$\Delta GDP_t = \alpha_0 + \alpha_1 GDP_{t-1} + \alpha_2 Infra_{t-1}^{+} + \alpha_3 \Delta Infra_{t-1}^{-} + \sum_{i=0}^{p} \beta_1 \Delta GDP_{t-1} + \sum_{i=0}^{q} \beta_2 \Delta Infra_{t-1}^{+} + \sum_{i=0}^{q} \beta_3 \Delta Infra_{t-1}^{-} + \epsilon_t$$

$$\Delta DC_t = \alpha_0 + \alpha_1 DC_{t-1} + \alpha_2 Infra_{t-1}^{+} + \alpha_3 \Delta Infra_{t-1}^{-} + \sum_{i=0}^{p} \beta_1 \Delta DC_{t-1} + \sum_{i=0}^{q} \beta_2 \Delta Infra_{t-1}^{+} + \sum_{i=0}^{q} \beta_3 \Delta Infra_{t-1}^{-} + \epsilon_t$$

Table 11 & 12, show that the NARDL with asymmetric long-run has been tested for four sectors (i.e., air infrastructure investment, air infrastructure investment, energy infrastructure investment) effect on the GDP and Domestic credit respectively.

Bounds-testing statistics as presented in the STATA, the null hypothesis being there is long run symmetry. The table presented below is the statistics summary for the asymmetric tests in STATA.

Table11: Bounds-testing statistics (Effect on **GDP**)

	Long Run		Short run		Selected Specification
	F-stat	P>F	F-stat	P>F	
Air	4.506	0.035	3.812	0.053	LR & SR Asymmetry
Road	5.236	0.024	4.406	0.038	LR & SR Asymmetry
Energy	7.896	0.006	47.09	0.000	LR & SR Asymmetry

Table12: Bounds-testing statistics (Effect on **Domestic Credit**)

	Long Run		Short run		Selected Specification
	F-stat	P>F	F-stat	P>F	
Air	20.77	0.000	3.192	0.076	LR & SR Asymmetry
Road	.1361	0.713	52.88	0.000	SR Asymmetry
Energy	1.786	0.183	17.08	0.000	SR Asymmetry

Table 13, we find that long-run positive coefficient of air infrastructure investment (L_{AIR}^{+}) is positive and significant at 1.472 unit, long-run negative coefficient of air infrastructure investment (L_{AIR}^{-}) is also positive and significant at 1%. The decrease of the investment in air infrastructure has higher negative impact compare to the positive. The short run ΔAIR_t^{+} is negative sign and the increase in air infrastructure investment does not give positive GDP contribution in the short run. Indicating investing in air infrastructure seen less impact in the short run to the GDP.

The investment in road infrastructure in China both in short run and long run will give a positive impact to the economic growth. The long run energy infrastructure investment coefficient L_{EN}^{+} is significant at 0.306. The increase in energy infrastructure investment in long run and short run will both contribute to the economic growth.

Table 13: Different Sectors' investment effect on Domestic Credit

Air to GDP NARDL with LR & SR Asymmetry		Road to GDP NARDL with LR & SR Asymmetry		Energy to GDP NARDL with LR & SR Asymmetry	
GDP_{t-1}	0.010*** (0.003)	GDP_{t-1}	0.0011 (0.0012)	GDP_{t-1}	0.007 (0.004)
AIR_{t-1}^{+}	-0.015 (0.009)	Road_{t-1}^{+}	0.0050* (0.0026)	En_{t-1}^{+}	-0.002 (0.001)
AIR_{t-1}^{-}	0.094** (0.044)	Road_{t-1}^{-}	0.0110 (0.0135)	En_{t-1}^{-}	-0.046*** (0.016)
ΔGDP_{t-1}	0.736*** (0.077)	ΔGDP_{t-1}	0.5891*** (0.0680)	ΔGDP_{t-1}	0.644** (0.075)
ΔGDP_{t-2}	0.267*** (0.088)	ΔGDP_{t-2}	0.2593*** (0.0762)	ΔGDP_{t-2}	0.273*** (0.085)
ΔGDP_{t-3}	-0.236*** (0.070)	ΔGDP_{t-4}	0.1235** (0.0587)	ΔGDP_{t-4}	-0.157** (0.062)
ΔAIR_t^{+}	-0.106* (0.055)	ΔRoad_t^{+}	0.0350*** (0.0082)	$\Delta \text{En}_{t-4}^{+}$	0.028*** (0.007)
		$\Delta \text{Road}_{t-1}^{+}$	0.0201*** (0.0067)		
ΔAIR_t^{-}	0.279*** (0.074)	$\Delta \text{Road}_{t-1}^{-}$	0.0580*** (0.0158		
$\Delta \text{AIR}_{t-2}^{-}$	-0.145* 0.074)	$\Delta \text{Road}_{t-2}^{-}$	0.0570*** (0.0159)		
		$\Delta \text{Road}_{t-3}^{-}$	0.0564*** (0.0157)		
		$\Delta \text{Road}_{t-4}^{-}$	0.1467*** (0.0200)		
Const	-6.253 (7.522)		5.1767*** (1.7150)		0.219 (1.951)
Long Run Coefficient					
L_{AIR}^{+}	1.472***	L_{ROAD}^{+}	-4.617	L_{EN}^{+}	0.306***
L_{AIR}^{-}	9.540***	L_{ROAD}^{-}	10.156	L_{EN}^{-}	-6.768

Notes: NARDL analysis is based on the variable per capita form. Thus, the effect is based on unit effect rather than a percentage effect. The standard error is in the parenthesis.

Table 14 is the NARDL test for the three sectors to the domestic private credit impact. The long run coefficient for positive investment in air infrastructure L_{AIR}^{+} is significant at 1% level, in which increase in 1 unit of the investment will increase the domestic private credit to increase 5.826,

meanwhile, in short run ΔAIR_t^{+}coefficient also shows a significant effect to the credit increase. The possible reason people would prefer to borrow more money to invest in the infrastructure sector. In the road investment, the long run coefficient both in positive and negative effects are significant, meaning more investment invest in the road infrastructure is coming from the borrowing from the bank institutions.

The increase in these sector investment in the long run will cause the domestic private credit increase. The road sector can be directed to the private parties by getting a concession agreement with the government, thus, more investment from private party to enter.

In the energy sector, the long run negative coefficient L_{EN}^{-} is significant, and both the short run positive short run negative are highly significant to the effect to the domestic private credit level. The decrease in the energy investment in the long run will also decrease the domestic private credit. Even though the energy sector is highly controlled by the government, the private parties would still prefer to go for higher leverage to access to the resources.

Although infrastructure has played a significant role in China's economic growth, but the effect of which in the long run will increase the private debt burden.

Table 14: Different Sectors' investment effect on Domestic Credit

Air to DC NARDL with LR & SR Asymmetry		Road to DC NARDL with SR Asymmetry		Energy to DC NARDL with SR Asymmetry	
DC_{t-1}	-0.012* (0.007)	DC_{t-1}	-0.022 (0.015)	DC_{t-1}	-0.033*** (0.010)
AIR_{t-1}^{+}	0.072*** (0.026)	Road_{t-1}^{+}	0.039** (0.019)	En_{t-1}^{+}	0.002 (0.002)
AIR_{t-1}^{-}	-0.142 (0.123)	Road_{t-1}^{-}	0.173** (0.083)	En_{t-1}^{-}	-0.399*** (0.080)
ΔDC_{t-1}	0.583*** (0.08)	ΔDC_{t-1}	0.591*** (0.080)	ΔDC_{t-1}	0.449*** (0.066)
ΔDC_{t-2}	0.214** (0.084)	ΔDC_{t-2}	0.233** (0.094)	ΔDC_{t-2}	0.190** (0.075)
		ΔDC_{t-4}	-0.283*** (0.089)	ΔDC_{t-4}	-0.237*** (0.068)
ΔAIR_t^{+}	-0.562** (0.219)	ΔRoad_t^{+}	0.002 (0.042)	ΔEn_t^{+}	0.136*** (0.035)

ΔAIR^{+}_{t-6}	0.622** (0.269)	$\Delta Road^{+}_{t-1}$	0.026 (0.032)	ΔEn^{+}_{t-1}	-0.063** (0.032)
				ΔEn^{+}_{t-4}	0.073*** (0.027)
ΔAIR^{-}_{t}	0.543* (0.289)	$\Delta Road^{-}_{t}$	-0.140 (0.095)	ΔEn^{-}_{t-1}	0.461*** (0.145)
ΔAIR^{-}_{t-2}	-0.670* (0.367)	$\Delta Road^{-}_{t-1}$	-0.183 (0.100)	ΔEn^{-}_{t-2}	0.518*** (0.142)
				ΔEn^{-}_{t-3}	0.558*** (0.140)
				ΔEn^{-}_{t-4}	1.175*** (0.159)
Const	3.902 (21.414)		1.444 (5.616)		-4.715 (5.982)
Long Run coefficient					
L^{+}_{AIR}	5.826***	L^{+}_{ROAD}	1.793***	L^{+}_{EN}	0.064
L^{-}_{AIR}	11.538	L^{-}_{ROAD}	-7.930***	L^{-}_{EN}	11.908***

Notes: NARDL analysis is based on the variable per capita form. Thus, the effect is based on unit effect rather than a percentage effect. The standard error is in the parenthesis.

The results are shown in Figure 2 & Figure 3, which plots the cumulative dynamic multipliers. These multipliers show the pattern of adjustment of economic growth and domestic credit towards its new long-term equilibrium respectively. Following a negative or positive unitary shock in air infrastructure investment, energy infrastructure investment and road investment. The positive and negative change curves provide the information about the asymmetric adjustment to positive and negative shocks at a given forecasting horizon. Lower band and upper band for asymmetry indicate the 95% confidence interval.

The graphs in Figure. 2 confirm the existence of an overall positive relationship in the infrastructure investment to the GDP and domestic credit. The effect of a positive shock in road infrastructure investment is found to dominate that of a negative shock with an initial positive effect. Moreover, a significant asymmetric response to shocks in road infrastructure investment is observed.

Similarly in Figure. 3 we note the positive association between air infrastructure investment to the domestic private credit level. This result indicates that a positive shock in financial development dominates a negative shock, confirming the result in table 14. Furthermore, an overall positive association exists in other two sectors.

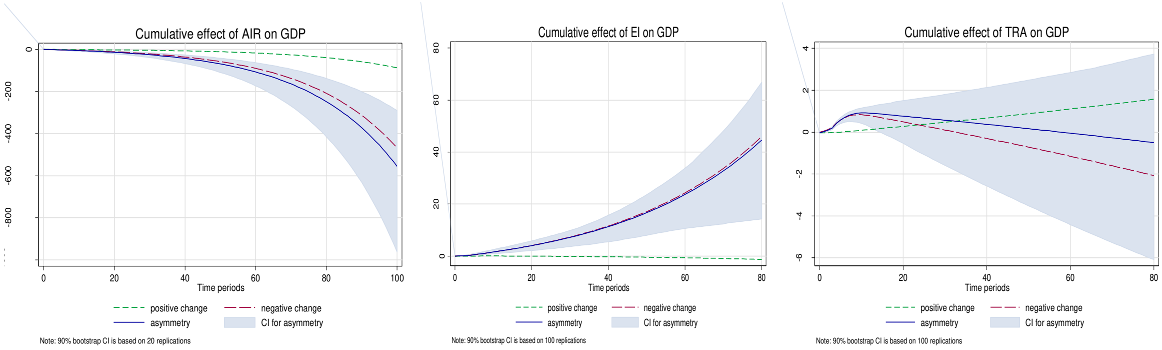


Figure. 2. Cumulative asymmetric adjustments of GDP to infrastructure investment sectors

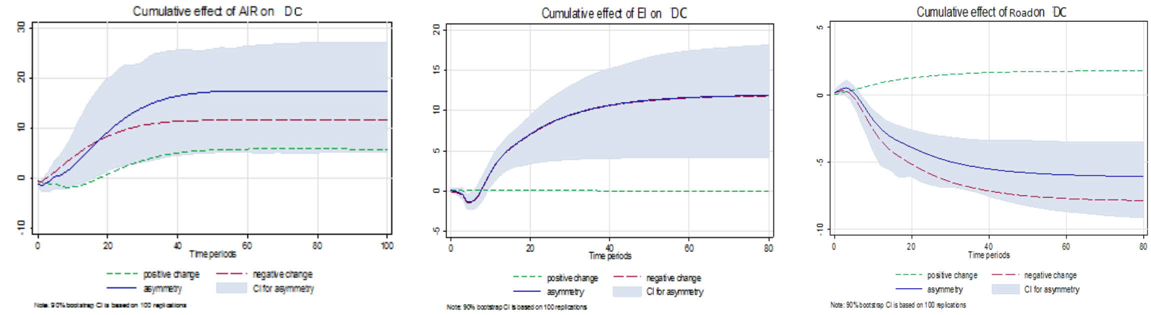


Figure. 3. Cumulative asymmetric adjustments of Domestic private credit level to infrastructure investment sectors

7. Conclusion

Air road and energy infrastructure has played a significant role in China's economic growth, but the huge investment in infrastructure has also resulted in a rapid growth of debt, which in turn has made China's leverage higher for the private parties. Government introduces financial resources into infrastructure investment with political connections, which leads to the allocation of financially less efficient private enterprises, which drags down the potential growth of the economy and leads to further rise in leverage. This empirical finding is important because it suggests that a stable investment in infrastructure is needed, while the efficiency of the management is also important. Government should care more about the debt level and reduce the debt leverage, as more debt will eventually drag the economy down.

Limitations of the study – Limitation 1: due to the time constraint, data limitations, more detailed analysis could not be done. A specific subject is the real estate investment, which should be included in this study with asymmetric impact on the economic growth and domestic private credit level. Limitation 2: the proxy in this paper may be biased, this is also due to the limitation to find more reliable data.

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