



THE LEAD-LAG RELATIONSHIPS BETWEEN CONSTRUCTION INVESTMENT AND GDP: GRANGER CAUSALITY TESTS AND IMPULSE RESPONSES USING JAPANESE DATA

Kazutaka Kurasawa¹

¹Associate Professor, Faculty of Management Information, Yamanashi Gakuin University, Kofu, Yamanashi, Japan

ABSTRACT

This paper analyzes the lead-lag relationships between construction investment and GDP at business-cycle frequency by the tests of Granger causality and the impulse responses in the framework of the vector autoregression, using the annual Japanese data. The analysis find that private construction investment tends to lead GDP, not vice versa, in the Granger sense and is of value in predicting the course of GDP one year ahead. Government construction investment, on the other hand, tends to lag GDP.

Keywords: Construction investment, GDP, Vector autoregression, Granger causality, Impulse responses, Business cycle.

JEL Classification: E32, E37.

Received: 3 March 2016 / Revised: 11 June 2016 / Accepted: 18 August 2016 / Published: 19 September 2016

Contribution/ Originality

This study is one of very few studies which have investigated empirically whether construction investment preceded the economic growth in business-cycle frequency within the methodological framework of Granger causality.

1. INTRODUCTION

Construction shares a large fraction of an economy's output. The value added of the construction sector ranges from 3-5% of gross domestic product (GDP) in developing countries to 5-8% in advanced countries (Han and Ofori (2001)). Construction investment, which includes construction-related imports as well, accounts for 7-13% of GDP in developing countries and 10-16% in advanced countries (Pheng (1994)). It is, thus, highly probable that activities in the construction sector have non-negligible impact on the aggregate economy, leading its overall expansions and contractions. From an opposing point of view, however, it is also likely that construction investment is derived demand from national output and, consequently, booms and busts in the construction sector lag general economic conditions (Akintoye and Skitmore (1994)). The lead-lag relationships between construction investment and GDP are, therefore, to be empirically investigated.

The relationships between construction and GDP have stimulated academic and practical interests in long-term economic development (see Anaman and Osei (2007); Wong *et al.* (2008); Yiu *et al.* (2004) for example). In the early stage of development, the share of the construction industry grows at a higher rate than the size of national income does. As for more developed economies, however, there are controversies about the patterns in which the share of the construction industry varies with economic growth (Bon (1991); Bon (1992); Bon and Pietroforte (1993)). Several studies, such as De Long and Summers (1993) and Lopes (1998) analyze whether more construction investment induces higher economic growth. Few studies, however, focus on short-term lead-lag relationships at

business-cycle frequency. One of the few exceptions is a study on quarterly investment flow in Hong Kong by Tse and Ganesan (1997) which concludes that GDP tends to lead construction, but not vice versa.

In the econometric literature, lead-lag relationships are often investigated by the Granger causality methodology (Granger (1969)). This methodology tests the predictive power of one variable to another in the vector autoregression (VAR). The VAR is a generalization of the univariate autoregression for multiple time-series and a system of regressions in which each variable is explained by lagged values of all variables in the system. The Granger causality methodology essentially tests whether lagged values of one variable are statistically significant in a regression of another variable in the VAR.

The VAR also generates impulse responses, which trace out how one variable responds to unexpected shocks to other variables in the system. Although the Granger causality test identifies which variables have predictive power, it is difficult to identify the timing from estimated coefficients in the multivariate system. Impulse responses instead reveal dynamic relationships between variables.

This paper analyzes the lead-lag relationships between construction investment and GDP at business-cycle frequency by the Granger causality methodology and the impulse responses generated from estimated VAR models, using the annual series from Japan. The Japanese government releases the time series data of GDP in the system of national accounts (SNA). It also regroups the SNA data into the annual series of various categories of construction investment. This paper utilizes these public sources of data and statistically tests whether GDP Granger causes construction investment or vice versa and identifies the signs and the durations of their dynamics.

The remainder of the paper is organized as follows. Section 2 describes the data used and presents the results of the unit root tests to determine whether GDP and construction investment are stationary. Since the test of Granger causality requires variables in the VAR are stationary, the stationarity of the data must be confirmed by the augmented Dickey-Fuller (ADF) test. Section 3 estimates the bivariate VAR models of GDP and construction investment and performs the tests of Granger causality in the estimated VAR models. Section 4 presents the impulse responses from some of the estimated VAR models. The last section concludes.

2. DATA AND UNIT ROOT TESTS

2.1. Data

The data in this section is annual time series for the period 1980-2005. The GDP data is sourced from the Cabinet Office of Japan (2016). The annual data of construction investment is obtained from the Ministry of Land, Infrastructure and Transport of Japan (2016), which regroups the GDP data into various categories of construction investment. Figure 1 describes how components of construction investment are categorized in the dataset. In what follows, we estimate the VAR models in which the logs of GDP and each category of construction investment form a bivariate system of endogenous variables.

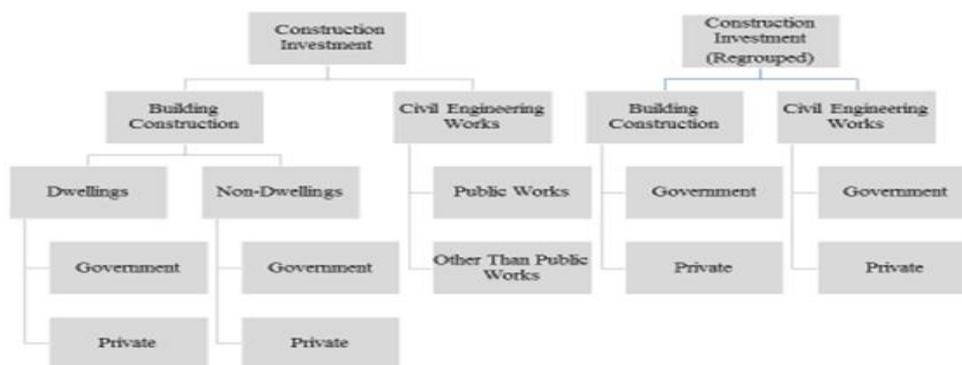


Figure-1. Categories of Construction Investment

Source Author:

2.2. Unit Root Tests

Before testing Granger causality, the order of integration of the variables must be determined by the unit root test since the Granger causality test requires that variables are stationary (Granger and Newbold (1974); Ong (1994)). Roughly speaking, a variable is integrated of order 1 if the original series has a unit root while the first difference does not; a variable is integrated of order 2 if the first difference has a unit root while the second difference does not (higher orders of integration are not considered here). In this paper, the ADF tests are carried out for unit roots on the logs of GDP x_t and construction investment y_t (Dickey and Fuller (1979)). For x_t , the ADF test is based on the regression

$$\Delta x_t = \alpha_0 + \alpha_1 t + \alpha_2 x_t + \sum_{i=1}^l \varphi_i \Delta x_{t-i} + e_t$$

Where t is a deterministic time trend, e_t is an error term, and α_0 , α_1 , α_2 and φ_i are all fixed coefficients. The lagged values of Δx_{t-i} are included to correct autocorrelation in e_t , The lag length l is determined by information criterions, such as the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (Akaike (1973) and Schwarz (1978)). The time trend t must be included in the regression not to reduce the power of the test.

The null and alternative hypotheses are

$$H_0: \alpha_2 = 0$$

$$H_1: \alpha_2 < 0$$

The null hypothesis implies that the variable x_t has a unit root, that is, it is non-stationary. The alternative hypothesis is that the variable does not have a unit root and is stationary along the deterministic trend. Unless the null hypothesis is rejected, the test is sequentially performed for the first difference $\Delta x_{t-1} = x_t - x_{t-1}$ and the second difference $\Delta^2 x_{t-1} = \Delta x_t - \Delta x_{t-1}$. Similarly, y_t , Δy_{t-1} and $\Delta^2 y_{t-1}$ are also tested for unit roots. The ADF statistic is known not to follow the Student t distribution; its distribution is generated through Monte Carlo simulations and tabulated by Engle and Granger (1987;1991).

Table-1. The Unit Root Tests for the Annual Series

Variable				Level			First Difference			Second Difference			
				ADF	p-value	Lag	ADF	p-value	Lag	ADF	p-value	Lag	
GDP				-1.00	0.93	1	-3.34	0.08	1	-5.28	0.00	1	
Construction Investment	Total			-1.00	0.93	1	-2.74	0.23	0	-6.08	0.00	0	
	Building construction	Total		-1.33	0.85	1	-3.33	0.09	0	-6.57	0.00	0	
		Dwellings	Total		-1.00	0.93	0	-4.37	0.01	0	-5.82	0.00	1
			Government		0.41	1.00	0	-1.65	0.74	0	-8.90	0.00	0
		Non-dwellings	Private		-1.08	0.91	0	-4.32	0.01	0	-5.84	0.00	1
			Total		-2.23	0.45	1	-3.24	0.1	1	-3.73	0.04	0
			Government		-0.83	0.95	1	-2.71	0.24	0	-5.09	0.00	1
	Private			-2.47	0.34	1	-3.4	0.08	1	-3.96	0.03	1	
	Civil engineering works	Total		0.05	0.99	1	-3.01	0.15	0	-6.29	0.00	1	
		Public works	Total		1.68	1.00	0	-3.57	0.06	0	-6.54	0.00	1
			Other than public works	Total		-1.38	0.84	1	-2.78	0.22	0	-6.83	0.00
	regrouped	Building construction	Government		-0.81	0.95	1	-2.36	0.39	0	-4.54	0.01	1
			Private		-1.54	0.78	1	-3.29	0.09	0	-6.34	0.00	0
		Civil engineering works	Government		1.69	1.00	0	-3.2	0.11	0	-6.67	0.00	0
Private				1.67	1.00	0	-3.57	0.06	0	-6.54	0.00	1	

Table 1 reports the results from the ADF tests on the levels, the first differences, the second differences of x_t and y_t . In some cases, the AIC and the BIC select different lag lengths, but the decisions whether to reject the null remain unchanged irrespective of the information criteria (the ADF statistics reported in Table 1 are from the regressions with the lag lengths selected by the AIC). The ADF statistics are compared with the critical values at the 5% significance level. Only “private dwellings” is integrated of order 1 and all the other variables are integrated of order 2.

3. VAR MODELS AND GRANGER CAUSALITY TESTS

The VAR is often used to describe the dynamic behaviors of multiple time series in economics and finance. In the bivariate VAR of GDP and construction investment in their second differences, the model has the form

$$\Delta^2 x_t = \beta_{10} + \sum_{i=1}^l \beta_{1i} \Delta^2 x_{t-i} + \sum_{i=1}^l \gamma_{1i} \Delta^2 y_{t-i} + u_t$$

$$\Delta^2 y_t = \beta_{20} + \sum_{i=1}^l \beta_{2i} \Delta^2 y_{t-i} + \sum_{i=1}^l \gamma_{2i} \Delta^2 x_{t-i} + v_t$$

Where u_t and v_t are error terms, and β 's and γ 's are all fixed coefficients (for “private dwellings”, which is integrated of order 1, Δx_t and Δy_t are used in place of $\Delta^2 x_t$ and $\Delta^2 y_t$). The value of the lag length l is determined by information criteria, such as AIC and BIC. Each equation of the model is fitted by the ordinary least squares (OLS).

The test of Granger causality is a joint F test on the coefficients γ 's. The null and alternative hypotheses are

$$H_0: \gamma_{j1} = \dots = 0$$

$$H_1: H_0 \text{ is not true.}$$

For $j = 1$ and 2 . The null hypothesis implies the lack of predictive power or no Granger causality.

Table 2 presents the F statistics from the Granger causality tests. In all the VAR models, the AIC and the BIC select identical lag lengths. The F statistics are compared with the critical values at the 5% significance level. The shaded cells indicate that the F statistics are statistically significant, concluding Granger causality.

Since the results are somewhat mixed, it is not possible to conclude that construction investment unambiguously Granger causes GDP. Some noticeable patterns, however, emerge from the results of the tests. In aggregate, construction investment Granger causes GDP, not vice versa, at annual frequency. This finding is at odds with [Tse and Ganesan \(1997\)](#) using quarterly data. Looking into the details, furthermore, private components, such as “private building construction”, tend to lead GDP while government expenditures, such as “government building construction” do not.

4. IMPULSE RESPONSES

Although the results of the Granger causality tests suggest which variables have predictive power, they do not identify the signs and the durations of their relationships. In general, feedback effects within the VAR are difficult to see from estimated coefficients because endogenous variables interact with each other in a complicated fashion.

Table-2. The Granger Causality Tests for the Annual Series

H0: Construction investment does not Granger cause GDP					
Variable				F	p-value
Construction Investment	Total			4.75	0.02
	Building construction	Total		9.74	0.00
		Dwellings	Total	8.90	0.00
			Government	1.34	0.27
			Private (1st diff.)	3.79	0.02
		Non-dwellings	Total	6.57	0.01
			Government	0.46	0.71
	Private		0.61	0.69	
	Civil engineering works	Total		1.28	0.30
		Public works	Total	0.38	0.68
		Other than public works	Total	0.53	0.59
	regrouped	Building construction	Government	1.95	0.15
			Private	9.71	0.00
		Civil engineering works	Government	2.15	0.12
Private			0.38	0.69	
H0: GDP does not Granger cause construction investment					
Variable				F	p-value
Construction Investment	Total			0.07	0.93
	Building construction	Total		0.91	0.47
		Dwellings	Total	4.96	0.03
			Government	0.36	0.70
			Private (1st diff.)	0.78	0.55
		Non-dwellings	Total	0.50	0.48
			Government	8.29	0.00
	Private		0.51	0.76	
	Civil engineering works	Total		1.86	0.15
		Public works	Total	1.04	0.37
		Other than public works	Total	4.43	0.02
	regrouped	Building construction	Government	4.67	0.02
			Private	1.11	0.38
		Civil engineering works	Government	1.85	0.16
Private			1.04	0.37	

Impulse responses, which are simulated as the trajectories of variables after an error term shocks the system by one standard deviation, instead reveal whether a change in one variable has a positive or negative impact on other variables and how long it takes for a shock to work through the system. In the VAR models estimated above, for example, the impulse responses of $\Delta^2 x_t$ to a shock v_t is defined as

$$\frac{\partial \Delta^2 x_{t+h}}{\partial v_t}$$

for $h = 0, 1, \dots$. The other impulse responses are similarly defined.

Figures 2.1-3 show the orthogonalized impulse responses for some of the variables that Granger cause the other variables in the systems. The orthogonalized impulse responses are generated under the assumption that a shock to one of the variables does not affect the other variable at $h=0$. In Figures 2.1 and 2.2, a shock to GDP is assumed not to affect “total construction investment” and “private building construction” at $h=0$. That is,

$$\frac{\partial \Delta^2 y_t}{\partial u_t} = 0$$

In Figure 2.3, it is assumed that a shock to “government building construction” does not affect GDP. That is,

$$\frac{\partial \Delta^2 x_t}{\partial v_t} = 0$$

In calculating impulse responses, orthogonalization is generally required to attribute a common component of error terms to one of variables. A common component is attributed to the variable that is hypothesized to precede the other variables in the system.

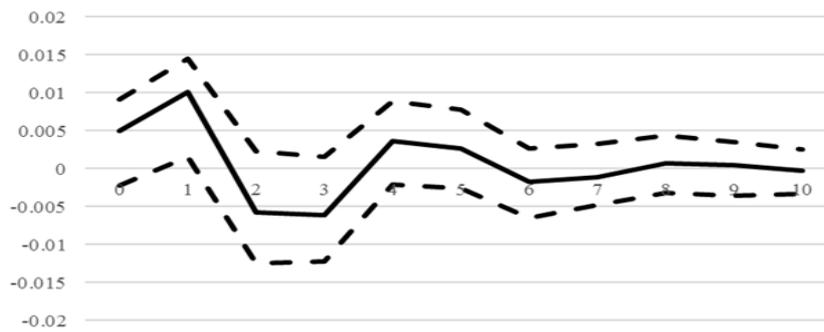


Figure-2.1. The Impules Responses Total Construction Investment to GDP

Source: Authour

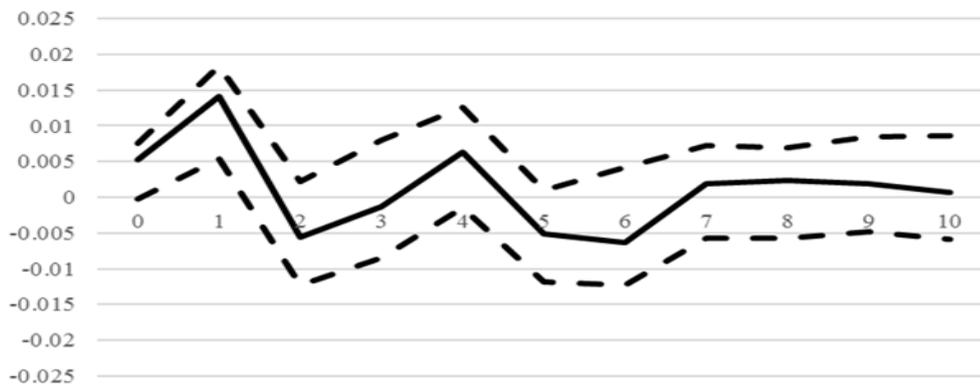


Figure-2.2. The Impules Responses from Private Building Constructions to GDP

Source: Authour

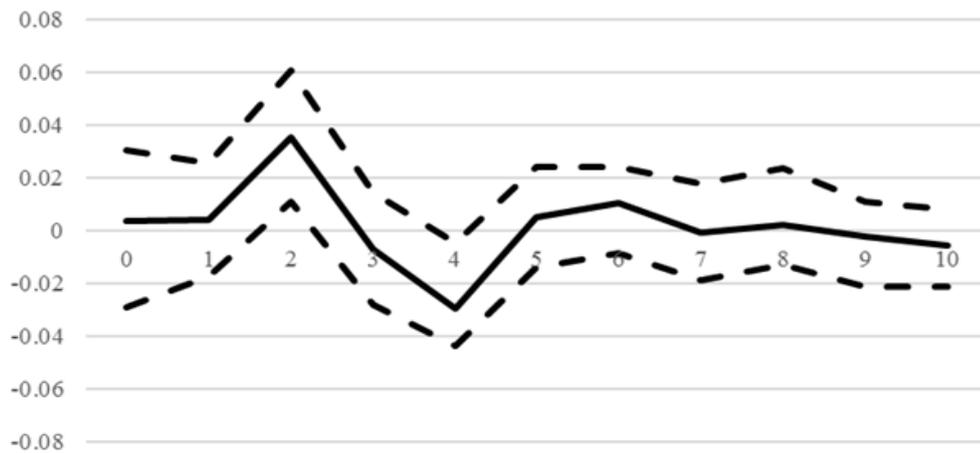


Figure-2.3. The Impules Responses from GDP to Government Building Constructions

Source: Authour

In the figures, the bold line are the impulse responses over a period of 10 years, and the dotted lines are 95% bootstrap confidence intervals. For all the variables, the impulse responses exhibit hump-shaped behaviors. The responses are positive and statistically significant from $h = 1$ or 2 and decay thereafter. The growth of GDP accelerates one year after shocks hits “total construction investment” and “private building construction”. It two years for a shock to GDP to have impact on “government building construction”.

5. CONCLUDING REMARKS

This study has investigated the lead-lag relationships between Japanese construction investment and GDP at annual frequency by the Granger causality tests and the impulse responses within the framework of the VAR. The results are not clear-cut, but construction investment tends to lead GDP and, in particular, private construction investment precedes the growth of GDP. This finding is important for macroeconomic policy in that conditions in the construction sector can have non-negligible impact on employment and national income. It is often argued that weak activity in construction causes slow economic growth for a classical example), which this study supports. This finding is, however, at odds with Tse and Ganesan (1997) concluding that GDP tends to lead construction. Further investigation is needed to identify factors that lead to these conflicting findings. Government construction investment is, on the other hand. Found to lag GDP.

Funding: This study received no specific financial support.

Competing Interests: The author declare that there are no conflict of interests regarding the publication of this paper.

REFERENCES

- Akaike, H., 1973. Maximum likelihood identification of Gaussian autoregressive moving average models. *Biometrika*, 60(2): 255-265.
- Akintoye, A. and M. Skitmore, 1994. Models of UK private sector quarterly construction demand. *Construction Management and Economics*, 12(1): 3-13.
- Anaman, K.A. and A.C. Osei, 2007. Analysis of the causality links between the growth of the construction industry and the growth of the macro-economy in Ghana. *Construction Management and Economics*, 25(9): 951-961.
- Bon, R., 1991. What do we mean by building technology? *Habitat International*, 15(1): 3-26.
- Bon, R., 1992. The future of international construction: Secular patterns of growth and decline. *Habitat International*, 16(3): 119-128.
- Bon, R. and R. Pietroforte, 1993. New construction versus maintenance and repair construction technology in the US since world war II. *Construction Management and Economics*, 11(2): 151-162.
- De Long, J.B. and L.H. Summers, 1993. How strongly do developing economies benefit from equipment investment? *Journal of Monetary Economics*, 32(3): 395-415.
- Dickey, D.A. and W.A. Fuller, 1979. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74(366a): 427-431.
- Engle, R.F. and C.W. Granger, 1987;1991. Co-integration and error correction: Representation, estimation, and testing. *Econometrica: Journal of the Econometric Society*, 55(2): 251-276.
- Granger, C.W., 1969. Investigating causal relations by econometric models and cross-spectral methods. *Econometrica: Journal of the Econometric Society*, 37(3): 424-438.
- Granger, C.W. and P. Newbold, 1974. Spurious regressions in econometrics. *Journal of Econometrics*, 2(2): 111-120.
- Han, S.S. and G. Ofori, 2001. Construction industry in China's regional economy, 1990-1998. *Construction Management & Economics*, 19(2): 189-205.
- Lopes, J., 1998. The construction industry and macroeconomy in Sub-Saharan Africa post 1970. *Construction Management & Economics*, 16(6): 637-649.

- Ong, E.O., 1994. Structural and vector autoregressive approaches to modelling real estate and property stock prices in Singapore. *Journal of Property Finance*, 5(4): 4-18.
- Pheng, L.S., 1994. Balancing construction and marketing in world economic development: The four global scenarios. *Construction Management and Economics*, 12(2): 171-182.
- Schwarz, G., 1978. Estimating the dimension of a model. *Annals of Statistics*, 6(2): 461-464.
- Tse, R.Y. and I.S. Ganesan, 1997. Causal relationship between construction flows and GDP: Evidence from Hong Kong. *Construction Management & Economics*, 15(4): 371-376.
- Wong, J.M., Y.H. Chiang and T.S. Ng, 2008. Construction and economic development: The case of Hong Kong. *Construction Management and Economics*, 26(8): 815-826.
- Yiu, C.Y., X.H. Lu, M.Y. Leung and W.X. Jin, 2004. A longitudinal analysis on the relationship between construction output and GDP in Hong Kong. *Construction Management and Economics*, 22(4): 339-345.

Views and opinions expressed in this article are the views and opinions of the author(s). The Economics and Finance Letters shall not be responsible or answerable for any loss, damage or liability etc. caused in relation to/arising out of the use of the content.