Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Asian Economics 15 (2004) 591–598
JOURNAL OF ASIAN ECONOMICS

Short communication

A note on testing the causal link between construction activity and economic growth in Taiwan

Tsangyao Chang[a,1], Chien-Chung Nieh[b,*]

[a]Department and Graduate Institute of Economics, Feng Chia University, Taichung, Taiwan
[b]Department of Banking & Finance, Tamkang University, Tamsui, Taipei 251, Taiwan

Received 10 June 2003; received in revised form 31 March 2004; accepted 15 April 2004

Abstract

In this note, using a four-variable VAR model, we empirically test the causal link between construction activity and economic growth in Taiwan over the 1979Q1–1999Q4 period. The cointegration results of Johansen [J. Econ. Dyn. Contr. 12 (1988) 231] and Johansen and Juselius [Oxford Bull. Econ. Stat. 52 (1990) 169] indicate that there exists a cointegrating vector among four variables—namely, real GDP, real investment in construction activity, real government expenditures, and real private consumption expenditures. Here, the results from Granger-causality tests based on corresponding vector error-correction models (ECM) clearly point to unidirectional causality running from construction activity to economic growth. This, the major finding of this study, has important implications with respect to developing economic policy regarding the role of construction activity in Taiwan over the test period.

JEL classification: C32; E62

Keywords: Construction activity; Economic growth; Cointegration; Granger causality

1. Introduction

The relationship between construction activity and economic growth has been extensively investigated over the past few decades (for example, Ball & Wood, 1996; Crosthwaite, 2000; Drewer, 1980; Strassmann, 1970; Turin, 1978; Wells, 1985). Early studies looked at the simple correlation between these two variables, with some testing the

* Corresponding author. Tel.: +886 2 26215656x2591; fax: +886 2 26214755.
E-mail addresses: tychang@fcu.edu.tw (T. Chang), niehcc@mail.tku.edu.tw (C.-C. Nieh).
[1] Tel.: +886 4 2451 7250x4484; fax: +886 4 2451 8737.

1049-0078/$ – see front matter
doi:10.1016/j.asieco.2004.04.003

construction activity–economic growth relationship by estimating various growth functions that included construction investment as an explanatory variable for cross-sections of developing countries (Akintoye & Skitmore, 1994). The association between construction activity and economic growth was merely assessed by looking at the sign and statistical significance of the coefficient of construction activity. Most previous studies found a positive correlation (and/or linear or nonlinear relationship) between GDP and various measures of construction activity. Although studies using this methodology may have proven to be somewhat useful in examining the construction activity–economic growth relationship, they have fully failed to provide any means with which to determine the direction of causality. More recent studies on the construction–growth relationship, however, have gone beyond those studies not only by looking at the significance of the coefficient of construction investment but also by addressing the issue of the direction of causation using techniques within the Granger (1969) framework. Tse and Ganesan (1997), for example, tested for Granger causality between construction activity and the aggregate economy, using quarterly data from Hong Kong, and they report empirical evidence of causality running from GDP to construction activity, but not vice versa. However, the methodology used in their study limits their results to a mere estimation of some short-run dynamics between the two variables and, hence, does not allow for the estimation of long-run equilibrium states. Moreover, Tse and Ganesan's (1997) results may have been biased due to the omission of some relevant variables.

Fortunately, recent advances in time series analysis—cointegration tests and the vector error-correction mechanism (VECM)—have given rise to more effective techniques to study the long-run equilibrium relationship among integrated variables. In this note, by using multivariate error-correction models (ECM), we primarily aim to investigate the causal link between construction activity and economic growth in the small developing economy of Taiwan over the 1979Q1–1999Q4 period. Several factors make Taiwan a most interesting arena to explore such a causal link. First, Taiwan has enjoyed striking economic progress over the last several decades. To cite a few examples, its annual average economic growth rate in the past decade was 6.21%, while in 1999 its per capita GNP was US$13,248. Second, by the end of 1999, Taiwan had become the world's fourteenth largest trading country with a foreign exchange reserve estimated at US$106.2 billion. Furthermore, for the past two decades (1979–1999), the percentage of construction activity expenditures to GDP was consistently maintained at a yearly average of about 5%. Last but not least, on account of Taiwan's liberalization of its economic institutions in the early 1980s, sufficient data are now available for researchers to evaluate the effects of economic liberalization on various economic phenomena.

The remainder of this note is organized as follows. Section 2 presents the data used. Section 3 describes the methodology used and discusses the findings. Section 4 presents the conclusions that are drawn.

2. Data

Our empirical analysis employs quarterly data on real GDP (rgdp), real investment in construction activity (rcnst), real government expenditures (reg), and real private consumption expenditures (rcp) for Taiwan over the 1979Q1–1999Q4 period (deflated by a GDP deflator, where 1996 = 100). All data are obtained from the AREMOS database of the Taiwan Ministry of Education. Since the data are not seasonally adjusted at their source, we seasonally adjust them using the X-11 routine from the EV-4.1 program. All the data series are transformed to logarithmic form to achieve stationarity in variance.

3. Methodology and empirical results

3.1. Unit root tests

A number of authors have pointed out that the standard ADF test is not appropriate for variables that may have undergone structural changes. For example, Perron (1989, 1990) and Zivot and Andrews (1992) showed that the existence of structural changes biases the standard ADF test towards nonrejection of the null of unit root. Hence, it would be incorrect to conclude that variables are nonstationary simply on the basis of results from standard ADF test. Perron (1990), therefore, developed a procedure to test the hypothesis that a given series $\{Y_t\}$ has a unit root with an exogenous structural break, which occurs at time T_B. However, Zivot and Andrews (1992, hereafter ZA) criticized this assumption of an exogenous break point and developed a unit root test procedure that allows an estimated break in the trend function under the alternative hypothesis. For this reason, it seems appropriate to treat the structural break as endogenous and to test the order of integration using the ZA procedure. ZA tests are represented by the following augmented regression equations:

$$\begin{aligned}
&\text{Model A}: \Delta Y_t = \mu_1^A + \beta_1^A t + \mu_2^A DU_t + \alpha^A Y_{t-1} + \textstyle\sum_{j=1}^{k}\theta_j \Delta Y_{t-j} + \varepsilon_t;\\
&\text{Model B}: \Delta Y_t = \mu_1^B + \beta_1^B t + \gamma^B DT_t^* + \alpha^B Y_{t-1} + \textstyle\sum_{j=1}^{k}\theta_j \Delta Y_{t-j} + \varepsilon_t; \text{ and}\\
&\text{Model C}: \Delta Y_t = \mu_1^C + \beta_1^C t + \mu_2^C DU_t + \gamma^C DT_t^* + \alpha^C Y_{t-1} + \textstyle\sum_{j=1}^{k}\theta_j \Delta Y_{t-j} + \varepsilon_t,
\end{aligned} \tag{1}$$

where $DU_t = 1$, and $DT_t^* = t - T_B$ if $t > T_B$, and 0 otherwise. Here T_B refers to a possible break point. Model A allows for a change in the level of the series, Model B allows for a change in the slope of the trend function, while Model C combines changes in the level and the slope of the trend function of the series. The sequential ADF test procedure estimates a regression equation for every possible break point within the sample and calculates the t-statistics for the estimated coefficients. This tests the null hypothesis of a unit root against the alternative hypothesis of a trend stationarity with a one-time break (T_B) at the intercept and the slope of the trend function at an unknown point in time. The null of a unit root is rejected if the coefficient of Y_{t-1} is significantly different from zero. The selected break point for each data series is T_B where the t-statistics for the null is minimized. Since the choice of lag length may k affect the test results, the lag length is selected following the procedures suggested by Perron (1989).

For the purpose of comparison, Panels A and B in Table 1 report the results of nonstationary tests for real GDP (lrgdp), real investment in construction activity (lrcnst), real government expenditures (lreg), and real private consumption expenditures (lrcp) using both the ADF and KPSS (Kwiatkowski et al., 1992) tests. We find each data series is

Table 1
ADF and KPSS unit root tests

	Panel A: ADF		Panel B: KPSS (η_{μ})	
	Level	Difference	Level	Difference
lrgdp	−1.085 (2)	−3.479* (2)	2.198* [3]	0.241 [3]
lrcnst	−0.620 (2)	−4.064* (2)	2.082* [3]	0.245 [3]
lreg	−2.084 (2)	−4.657* (2)	2.157* [3]	0.316 [3]
lrcp	−0.129 (2)	−3.604* (2)	2.207* [3]	0.153 [3]

Note: The number in parentheses indicates the selected lag order of the ADF model. Lags are chosen based on Perron's (1989) method. The number in brackets indicates the lag truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987). Critical values for ADF and KPSS are taken from Mackinnon (1991) and Kwiatkowski et al. (1992), respectively.

* Significance at the 5% level.

nonstationary in levels but stationary in the first differences, suggesting that all the data series are integrated of order one. Table 2 shows the minimum t-statistics corresponding to Models A and C. The test results summarized in Table 2 provide evidence for the existence of a unit root when breaks are allowed. The plausible breaks for the series occur at 1985Q1, 1991Q1, 1989Q4, and 1987Q4, respectively, for real GDP, real investment in construction activity, real government expenditures, and real private consumption expenditures. On the basis of these results, we proceed to test whether these four variables can be cointegrated using the Johansen method.

3.2. Cointegration tests

Following Johansen (1988) and Johansen and Juselius (1990), we construct a p-dimensional (4×1) vector autoregressive model with Gaussian errors expressed by its first-differenced error-correction form as:

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \cdots + \Gamma_{k-1} \Delta Y_{t-k+1} - \Pi Y_{t-1} + \mu + \varepsilon_t, \quad (2)$$

where Y_t are the data series studied; ε_t is i.i.d. $N(0, \Sigma)$, $\Gamma_i = -I + A_1 + A_2 + \cdots + A_i$, for $i = 1, 2, \ldots, k-1$; and $\Pi = I - A_1 - A_2 - \cdots - A_k$. The Π matrix conveys information about the long-run relationship between Y_t variables, and the rank of Π is the number of

Table 2
Zivot–Andrews unit root tests for one break

	Model	Break	$t(\hat{\lambda}_{\text{inf}})$
lrgdp	A	1985Q1	−4.478
lrcnst	C	1991Q1	−2.135
lreg	C	1989Q4	−3.191
lrcp	A	1987Q4	−3.847

Note: Model specifications (i.e., which model, A, B, or C, is appropriate) are determined by first running each data series on Model C, with the possibility of both a slope and a level break. Model C is chosen if both dummy variables are significant. If only the slope dummy variable is significant, Model B is estimated. If only the level dummy is significant, Model A is estimated. Critical values are taken from Zivot and Andrew (1992). The 10 and 5% critical values are −4.58 and −4.80, respectively, for Model A, and −4.82 and −5.08, respectively, for Model C.

Table 3
Cointegration tests using the Johansen (1988) and Johansen and Juselius (1990) approach

	Trace test	5% critical value	10% critical value
lrgdp lrcnst lreg lrcp (VAR lag = 4)			
$H_0: r = 0$	51.88*	47.21	43.95
$H_0: r \leq 1$	26.61	29.68	26.79
$H_0: r \leq 2$	9.77	15.41	13.33
$H_0: r \leq 3$	0.46	3.76	2.69

Note: Critical values are taken from Osterwald-Lenum (1992). r denotes the number of cointegrating vectors. Schwartz Criteria (SC) is used to select the number of lags required in the cointegrating test. The computed Ljung–Box Q-statistics indicates that the residuals are white noise.

* Significance at the 5% level.

linearly independent and stationary linear combinations of the variables studied. Thus, testing for cointegration involves testing for the rank of the Π matrix r by examining whether the eigenvalues of Π are significantly different from zero.

Johansen (1988) and Johansen and Juselius (1990) proposed two test statistics for identifying the number of cointegrating vectors (or the rank of Π), namely the Trace (T_r) and the maximum eigenvalue (L-max) statistics. It is well known that Johansen's cointegration test is very sensitive to the choice of lag length. Here, the Schwartz Criteria (SC) is used to select the number of lags required in the cointegration test. A VAR model is first fit to the data to find an appropriate lag structure. SC suggests four lags for our VAR model. Table 3 presents the results from the cointegration tests of Johansen (1988) and Johansen and Juselius (1990). According to Cheung and Lai (1993), the Trace test shows more robustness to both skewness and excess kurtosis in the residuals than does the L-max test; therefore, we use only Trace (T_r) statistics in this study. As shown in Table 3, the Trace (T_r) statistics suggest that only one cointegrating vector exists among these four variables. This implies that these four variables would not move too far away from each other, thus displaying a co-movement phenomenon for real GDP, real investment in construction activity, real government expenditures, and real private consumption expenditures in Taiwan over this test period.

3.3. Granger-causality results based on the error-correction model (ECM)

Granger (1988) pointed out that if there exists a cointegrating vector among variables, then there must be causality among these variables at least in one direction. Granger (1986) and Engle and Granger (1987) provided tests of causality, which take into account the information provided by the cointegrated properties of variables. The model can be expressed as an ECM as follows (Engle and Granger, 1987):

$$\Delta Y_{it} = \mu_{it} + \beta' Z_{t-1} + \sum_{i=1}^{m} a_i \Delta Y_{1,t-i} + \sum_{i=1}^{m} b_i \Delta Y_{2,t-i} + \sum_{i=1}^{m} c_i \Delta Y_{3,t-i} + \sum_{i=1}^{m} d_i \Delta Y_{4,t-i} + \varepsilon_{it} \tag{3}$$

where Y_{it} denotes real GDP, real investment in construction activity, real government expenditures, or real private consumption expenditures and $\beta' Z_{t-1}$ contains r cointegrating

Table 4
Granger-causality results based on parsimonious vector error-correction models (VECM)

Explanatory variables	dlrgdp	dlrcnst	dlreg	dlrcp
Short run: F-statistic				
dlrgdp (−1)	–	0.98 (−4)	2.31 (−4)**	0.15 (−2)
dlrcnst (−1)	3.49 (−4)*	–	0.02 (−2)	1.12 (−1)
dlreg (−1)	4.99 (−3)*	0.58 (−2)	–	2.97 (−1)**
dlrcp (−3)	0.33 (−1)	0.39 (−2)	3.47 (−1)**	–
ECT: t-statistic	0.69	0.37	−0.42	−3.32*
Joint (short run/ECT): F-statistic				
dlrgdp/ECT	–	1.43 (−4)	1.85 (−4)	4.16 (−2)*
dlrcnst/ECT	2.79 (−4)*	–	0.07 (−2)	8.15 (−1)*
dlreg/ECT	4.21 (−3)*	0.44 (−2)	–	7.74 (−1)*
dlrcp/ECT	0.41 (−1)	0.33 (−2)	1.85 (−1)	–

Note: The number in the parentheses indicates the lag orders selected based on Akaike's (1974) FPE criterion.
* Significance at the 5% level.
** Significance at the 10% level.

terms, reflecting the long-run equilibrium relationship among variables. From the system, the Granger-causality tests are examined by testing whether all the coefficients of $\Delta Y_{2,t-i}$, $\Delta Y_{3,t-i}$, or $\Delta Y_{4,t-i}$ are statistically different from zero as a group based on a standard F-test and/or whether the β' coefficient of the error-correction is also significant.[2] Since Granger-causality tests are very sensitive to the selection of lag length, the lag lengths are determined using Hsiao's (1979, 1981) sequential procedure, which is based on the Granger definition of causality and Akaike's (1974) minimum final prediction error (FPE) criterion.

Table 4 presents the results from our Granger-causality tests based on vector ECM. They clearly show that unidirectional causality runs from construction activity (and/or real government expenditures) to economic growth (both in the short- and long-run senses). These results are consistent not only with the views of neoclassical models of economic growth but also with those of Keynesian state according to which economic growth is determined by other exogenous factors, such as investment or fiscal policy variables. Further, we find that the error-correction term (ECT) is only significant for the equation that includes private consumption expenditures. Our interpretation is that, over time, whenever there is a deviation from the equilibrium cointegrating relationship, as measured by the ECT, in order to restore the long-term relationship within the system, it is the private consumption expenditures that must bear the brunt of adjustment rather than real GDP or real government expenditures. Worth pointing out here is that our results are not consistent with those found in previous empirical studies which provide evidence of causality running from economic growth to construction activity, but not vice versa. For example, see Tse and

[2] Following the suggestion of one anonymous referee, we also investigate causality in a control sense and super exogeneity as in Engle and Hendry (1993). We find that the results are similar to those found in this study and that the construction expenditure variable also passes the super exogeneity test. These results are available upon request.

Ganesan (1997) for the situation in Hong Kong, Blomstrom et al. (1996) for that in the US, and Madson (2002) for the situation in 18 OECD countries. One explanation for our results is that, for the past two decades (1979–1999) in Taiwan, the percentage of construction activity expenditures to GDP has continually been maintained at an average value of about 5% per year. The major finding of our study has important implications for the conduct of economic policy regarding the role of construction activity in Taiwan over this test period. Simply put, it can be stated with confidence that increasing construction activity in Taiwan has served as a catalyst for remarkable economic growth.

4. Conclusions

In this note, we empirically investigate the causal link between construction activity and economic growth, using multivariate ECM, for Taiwan over the 1979Q1–1999Q4 period. The cointegration test results of Johansen (1988) and Johansen and Juselius (1990) indicate that the four variables—namely, real GDP, real investment in construction activity, real government expenditures, and real private consumption expenditures—are cointegrated with one vector. The results from Granger-causality tests based on the corresponding vector ECM are indicative of unidirectional causality running from construction activity (and/or real government expenditures) to economic growth (both short- and long run). In light of the important role that construction activity plays in Taiwan over this test period, the empirical finding of this study has important implications for the conduct of economic policy.

Acknowledgements

The authors acknowledge this journal's Editor Dr. Dutta and three anonymous referees for their helpful comments and suggestions that have greatly enhanced the quality of this paper.

References

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transaction on Automatic Control*, *AC-19*, 716–723.

Akintoye, A., & Skitmore, M. (1994). Models of UK private sector quarterly construction demand. *Construction Management and Economics*, *12*(1), 3–13.

Ball, M., & Wood, A. (1996). Does building investment affect economic growth? *Journal of Property Research*, *13*(2), 99–114.

Blomstrom, M., Lipsey, R. E., & Zejan, M. (1996). Is fixed investment the key to economic growth. *The Quarterly Journal of Economics*, 269–276.

Cheung, Y., & Lai, K. (1993). Finite-sample sizes of Johansen's likelihood ratio tests for cointegration. *Oxford Bulletin of Economics and Statistics*, *55*, 313–328.

Crosthwaite, D. (2000). The global construction market: A cross-sectional analysis. *Construction Management and Economics*, *18*, 619–627.

Drewer, S. (1980). Construction and development: A new perspective. *Habitat International*, *5*(4), 395–428.

Engle, R., & Granger, C. W. J. (1987). Cointegration and error correction: Representation, estimation, and testing. *Econometrica*, *55*, 251–276.

Engle, R., & Hendry, D. F. (1993). Testing super exogeneity and invariance in regression model. *Journal of Econometrics*, *56*, 119–139.

Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, *37*, 424–438.

Granger, C. W. J. (1986). Developments in the study of co-integrated economic variables. *Oxford Bulletin of Economics and Statistics*, *48*, 213–228.

Granger, C. W. J. (1988). Some recent developments in a concept of causality. *Journal of Econometrics*, *39*, 199–211.

Hsiao, C. (1979). Causality in econometrics. *Journal of Economic Dynamics and Control*, *4*, 321–346.

Hsiao, C. (1981). Autoregressive modeling and money-income causality detection. *Journal of Monetary Economics*, *7*, 85–106.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, *12*, 231–254.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—With applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, *52*, 169–210.

Kwiatkowski, D., Phillips, P., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? *Journal of Econometrics*, *54*, 159–178.

Mackinnon, J. (1991). In Engle & Granger (Eds.), *Critical values for cointegration tests in long-run economic relationships—Readings in cointegration* (pp. 267–276). New York: Oxford University Press.

Madson, J. B. (2002). The causality between investment and economic growth. *Economic Letters*, *74*, 157–163.

Newey, W., & West, K. (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica*, *55*, 703–708.

Osterwald-Lenum, M. (1992). A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics. *Oxford Bulletin of Economics and Statistics*, *54*, 461–472.

Perron, P. (1989). The great crash, the oil price shock and the unit root hypothesis. *Econometrica*, *57*(6), 1361–1401.

Perron, P. (1990). Testing for a unit root in a time series with a changing mean. *Journal of Business and Economic Statistics*, *8*(2), 153–162.

Strassmann, P. (1970). The construction sector in economic development. *The Scottish Journal of Political Economy*, *17*(3), 390–410.

Tse, R. Y. C., & Ganesan, S. (1997). Causal relationship between construction flows and GDP: Evidence from Hong Kong. *Construction Management and Economics*, *15*, 371–376.

Turin, D. (1978). Construction and development. *Habitat International*, *3*(1), 33–45.

Wells, J. (1985). The role of construction in economic growth and development. *Habitat International*, *9*(1), 55–70.

Zivot, E., & Andrews, D. W. K. (1992). Further evidence on the great crash, the oil-price shock, and the unit root hypothesis. *Journal of Business and Economic Statistics*, *10*, 251–270.