Does Telecommunications Investment Cause Economic Growth: Evidence from Korea

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Abstract

This paper examines the causality issue between telecommunications investment and economic growth for South Korea by applying recently developed time series techniques. Tests for unit roots, co-integration, and Granger causality are presented. The results show that bi-directional causality runs from telecommunications investment to economic growth for South Korea. This means that increased telecommunications investment directly affects economic growth and an increase in real income also influences telecommunications investment. The study also discusses the implications of the results for addressing telecommunications policy in South Korea.

Keywords: Telecommunications investment, economic growth, Granger causality, unit root, co-integration

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1. Introduction

In the past two decades a number of studies have examined the relationship between telecommunications investment and economic growth (e.g., Hardy, 1980 Leff, 1984; Wilson & Teske, 1990; Norton, 1992; Saunders, et al., 1994; Edirisuriya, 1995).[1] Most of the studies have found that there is a strong positive relationship between telecommunications investment and economic growth. For example, using statistical data for the 50 states of the United States (US), Dholakia & Harlam (1994) conducted a multiple regression analysis and found the influence of telecommunications on economic development is very strong when it is viewed as the only developmental input as well as when it is compared with other inputs such as education, energy and physical infrastructure. More recently, Wang (1999) empirically detected the strong impact of telecommunications investment on economic growth in Taiwan.

The strong positive relationship between telecommunications and growth suggests that telecommunications investment is an important determinant of the rate of economic growth. However, as explained by Blomstrom et al. (1996) and Madden & Savage (1998), the finding of a strong association between investment and growth does not necessarily imply a "causal" relationship. The relationship may very well run from economic growth to telecommunications investment, and/or from telecommunications investment to economic growth. These causality issues therefore merit further investigation. At the heart of this issue arises the question as to which variable takes precedence over the other – is telecommunications a stimulus for economic growth or does economic growth lead to telecommunications investment? Evidence on either direction may have significant bearing upon policy.

The direction of causation between telecommunications investment and economic growth has significant policy implications. If, for example, there exists uni-directional causality running from telecommunications investment to economic growth, reducing telecommunications investment could lead to a fall in income. In the case of negative causality running from telecommunications to economic growth, total income could rise if policies for reducing telecommunications investment were to be implemented. On the other hand, if

[1] A good overview of the literature is found in Maddock (1995).

uni-directional causality runs from income to telecommunications, it may be implied that policies for reducing telecommunications investment may be implemented with little adverse or no effects on economic growth. The finding of no causality in either direction, the so-called 'neutrality hypothesis', would indicate that policies for increasing telecommunications investment do not affect economic growth.

In a summary of the literature on the causal relationship between telecommunications investment and economic growth, the seminal study by Cronin et al. (1991) provided evidence to support bi-directional causality running from the amount of telecommunications investment and the level of economic activity in the case of US over the period 1958-1988 using the Granger and modified Sims techniques. This finding was supported by Cronin et al. (1993) who tested for the causal relationship between telecommunications infrastructure investment and economic growth at the more localized state and sub-state level and for specific sub-categories of telecommunications infrastructure investment – central office equipment and cable and wire. They also found bi-directional causality consistent with the previous US national-level analysis. Zhu (1996) attempted to examine the causal relationship running from telecommunications investment to economic development only using a pooled time series analysis based on 17 year's data from 23 countries, and found telecommunications investment significantly contribute to economic development. More recently, Madden and Savage (1998) analyzed the relationship between telecommunications infrastructure investment and economic growth for a sample of transitional economies in Central and Eastern Europe. The study showed that overall, there appears to be two-way, or mutual causality between telecommunications investment and real economic growth at the aggregate level.

Public policy makers in developing countries such as South Korea, as well as in developed countries, have shown a great deal of interest in inquiring about the role that telecommunications investment plays in the economic development. The telecommunications infrastructure of South Korea is becoming an increasingly important component of the economy (Ministry of Information and Communications, 1999). In addition, as commonly known, telecommunications enhances the productivity of capital, labor, and other factors of production (Schwartz, 1990). To proactively cope with increasing telecommunications demand accompanying rapid economic growth, South Korea should endeavor to uncover role of telecommunications investment in economic growth and to make appropriate telecommunications policy. This task has become one of the most important ones for South Korea in the present and in the near future.

The purpose of this paper is therefore to examine causality between telecommunications investment and economic growth, and to obtain policy implications of the results. To this end, we attempt to provide more careful consideration of the causality issues by applying recently developed rigorous techniques of Granger causality to South Korean data. The methods adopted here are in the following fashion. First, we test stationarity and co-integration; second, instead of arbitrarily choosing a lag length, we employ statistical methods to select the optimum lag; third, we perform Hsiao's version of the Granger causality method to estimate causality (Granger, 1969; Hsiao, 1981); finally, we perform the F-test to gauge the joint significance levels of causality between the two variables.

The remainder of the paper is organized as follows. Section 2 presents an overview of the proposed methodology and explains the data employed. The penultimate section reports the empirical findings. A summary, some policy implications and conclusions of the study are made in the final section.

2. Methodology and data

2.1 Granger causality test and stationarity

The first attempt at testing for the direction of causality was proposed by Granger (1969). Granger's test is a convenient and very general approach for detecting the presence of a causal relationship between two variables. The Granger causality test is quite simple and straightforward. A time series (X) is said to Granger-cause another time series (Y) if the prediction error of current Y declines by using past values of X in addition to past values of Y. The Granger's causality test method is chosen in this study over alternative techniques in the light of the favorable Monte Carlo evidence reported by Guilkey and Salemi (1982) and Geweke et al. (1983), particularly for small samples in applied work.

The application of the standard Granger causality test requires the series of variables to be stationary. It has been shown that using non-stationary data in causality tests may yield spurious causality results (Granger & Newbold, 1974; Stock & Watson, 1989). Therefore, following Engle & Granger (1987), we first test the unit roots of X and Y to ensure the stationarity of each variable by using the Phillips-Perron test (Phillips & Perron, 1988). The test is known to be robust for a variety of serial correlations and time-dependent heteroscedasticities. If any variable is found to be non-stationary, we must take the first difference and then apply the causality test with differenced data.

To test for Granger causality between X and Y, two bivariate models are specified, one for X and another for Y. If two variables are non-stationary but they become stationary after first differencing, the standard form of the Granger causality test can be specified accordingly as follows:

$$\Delta Y_t = \alpha_{11} + \sum_{i=1}^{L_{11}} \beta_{11i} \Delta Y_{t-i} + u_{11t} \tag{1}$$

$$\Delta Y_t = \alpha_{12} + \sum_{i=1}^{L_{11}} \beta_{11i} \Delta Y_{t-i} + \sum_{j=1}^{L_{12}} \beta_{12j} \Delta X_{t-j} + u_{12t} \tag{2}$$

$$\Delta X_t = \alpha_{21} + \sum_{i=1}^{L_{21}} \beta_{21i} \Delta X_{t-i} + u_{21t} \tag{3}$$

$$\Delta X_t = \alpha_{22} + \sum_{i=1}^{L_{21}} \beta_{21i} \Delta X_{t-i} + \sum_{j=1}^{L_{22}} \beta_{22j} \Delta Y_{t-j} + u_{22t} \tag{4}$$

where Δ is the difference operator, L is the number of lags, α and β are parameters to be estimated, and u_t is the error term.

Equations (2) and (4) are in unrestricted forms, while equations (1) and (3) are in restricted forms. However, equations (1) and (2) are made a pair to detect whether the coefficients of the past lags of X can be zero as a whole. By the same token, equations (3) and (4) are made other pair to detect whether the coefficient of the past lags of Y can be zero as a whole. Stated differently, if the estimated coefficient on lagged values of X in equation (2) is significant, it indicates that it explains some of the variance of Y that is not explained by the lagged values of Y itself. This implies that X is causally prior to Y and said to Granger-cause Y. Similarly, if the estimated coefficient on lagged values of Y in equation (4) is significant, it indicates that it explains some of the variance of X that is not explained by lagged values of X itself. This means that Y is causally prior to X and said to Granger-cause X. Thus, F-statistics are calculated to test whether the coefficients of lagged values can be zero.

2.2 Co-integration

The concept of co-integration can be defined as a systematic co-movement among two or more economic variables over the long run. According to Engle & Granger (1987), if X and Y are each non-stationary, one would expect that a linear combination of X and Y would be a random walk. However, the two variables may have the property that a particular combination of them $Z = X - bY$ is stationary. Thus, if such a property holds true, then we say that X and Y are co-integrated.

If X and Y each are non-stationary and co-integrated, then any standard Granger causal inferences will be invalid and a more comprehensive test of causality based on an error-correction model, should be adopted (Engle & Granger 1987). However, if X and Y each are non-stationary and the linear combination of the series of two variables is non-stationary, then standard Granger causality test should be adopted (Toda & Phillips, 1993). Therefore, it is necessary to test for the co-integration property of the series of telecommunications investment and economic growth before performing the standard Granger causality test.

In the error-correction modeling procedure, X Granger-cause Y, if either the estimated coefficients on lagged values of X or the estimated coefficient on lagged value of error term from co-integrated regression is statistically significant. Similarly, Y Granger-cause X, if either the estimated coefficients on lagged values of Y or the estimated coefficient on lagged value of error term from co-integrated regression is statistically significant. This procedure specifically allows for a causal linkage between two or more variables stemming from an equilibrium relationship, thus characterizing the long-run equilibrium alignment that persists beyond the short-run adjustment.

2.3 Hsiao version of the Granger causality method

The causal results are sensitive to the lag structure of the independent variables. The arbitrariness in choosing lags can distort the estimates and yield misleading causality inferences. Hsiao's (1981) procedure combining the Akaike's

(1969) final prediction error (FPE) criterion with Granger causality test will be employed in this study to guide the selection of the appropriate lag specifications. This FPE rule rewards good fit but penalizes the loss of degree of freedom.[2] Hsiao's procedure consists of two steps. The first step is to estimate equation (1) to compute the residual sum of squares by varying the lag order (l_{11}) from 1 to L_{11}. The $FPE(l_{11})$, which represents the lag consideration, is computed as:

$$FPE(l_{11}) = \left[\frac{T + l_{11} + 1}{T - l_{11} - 1}\right] \cdot \frac{RSS(l_{11})}{T}, \qquad (5)$$

where T is the sample size and RSS is the residuals sum of squares from (1). Thus, if L_{11} in equation (1) is set at 5, then there are 5 FPEs.

The smallest $FPE(l_{11})$ decides the optimal lag (l_{11}^*). The second step is to estimate equation (2). For additional variable X, one varies again the lag order (l_{12}) from 1 to L_{12} and calculates the modified two-dimensional FPE as:

$$FPE(l_{11}^*, l_{12}) = \left[\frac{T + l_{11}^* + l_{12} + 1}{T - l_{11}^* - l_{12} - 1}\right] \cdot \frac{RSS(l_{11}^*, l_{12})}{T}. \qquad (6)$$

Also, the smallest $FPE(l_{11}^*, l_{12})$ decides the optimal lag (l_{12}^*). Thus, the appropriate lags (l_{11}^*, l_{12}^*) are determined. If $FPE(l_{11}^*, l_{12}^*)$ is smaller than the $FPE(l_{11}^*)$, it implies that X Granger-cause Y. Subsequently, causality from Y to X may also be estimated by repeating the same procedure for equations (3) and (4). Thus, by combining the FPE criterion and Granger's definition of causality, Hsiao's (1981) method would allow two variables to enter the equation with different number of lags. As a result, there is a reduction in the number of lags to be estimated.

The maximum order L_{11}, L_{12}, L_{21} and L_{22} can be set to be sufficiently large in order not to miss the global minimum FPE. In actual practice, the researchers' choice for maximum lag length order is likely to be influenced by the

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[2] The Akaike's FPE criterion is quite appealing because "it balances the risk due to bias where a lower order is selected and risk due to the increase of variance when a higher order is selected" (Hsiao, 1981, p. 88).

length and nature (annual or quarterly) of time series and the number of variables entering into the equation. Since our annual time series data do not exceed 35 years for the variables, we set the maximum order to 6.

2.4 Variable definition and data sources

In order to investigate whether there is a causal relationship between telecommunications investment and gross domestic product (GDP), data covering the period 1965-1998 are used.[3] The choice of the starting period was constrained by the availability of data on telecommunications investment. The nominal GDP series and the telecommunications investment series in Korean currency units (won) are transformed into real GDP and real telecommunications investment in constant 1995 prices, respectively, using GDP deflators.[4] The variables used in the models are: GDP, real GDP; $TINV$, real telecommunications investment. The GDP variable is complied from World Bank (2000) and the $TINV$ variable is obtained from International Telecommunications Union (2000).

Our empirical work was complicated by the fact that some of observations for $TINV$ were missing (10 observations for the period 1966-1969, 1971-1974 and 1980-1981). A straightforward solution to the missing-observations problem is simply to drop the missing observations from consideration, leading to a loss of efficiency. Alternatively, replacing the missing observations by the sample mean of the available observations on $TINV$ can be considered. However, in doing time-series analysis adopted here, we should take account for the fact that most time-series variables tend to undergo relatively predictable rates of growth. To do this, we should search for proxy variables that are highly correlated with the variables whose observations are missing. One better and useful solution to the time-series problem would involving replacing missing observations with proxy observations obtained by regressing the known values of the $TINV$ on time and then replacing the missing observations with the fitted values of the regression (Pindyck & Rubinfeld, 1997, pp. 246-250). We have experimented with a number of specifications using observable data on $TINV$, obtaining the following best

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[3] The use of GDP, rather than GNP, may be more appropriate in the analysis of the causal relationship, because the country's total telecommunications investment depends upon goods and services produced within the country, not outside the country.

fitting result (t-statistics in parentheses):

$$\ln TINV = 17.84 + 0.41 \cdot T + 0.0049 \cdot T^2, \quad R^2 = 0.999, F = 1759.67$$
$$(130.21) \quad (13.27) \quad (3.01)$$

where ln stands for natural logarithm, T is a time variable (from 1965 = 1 to 1983 = 19), and F means F-statistic under the null hypothesis that all the parameters are jointly zero. The reason for the choice of the ending period 1983 for the regression is that South Korea's drastic economic takeoff started to reveal in mid-1980 by transforming a traditional agrarian economy to an export-led economy.

3. Empirical results

3.1 Results from unit roots and co-integration tests

Following the practice of Cronin et al. (1991), when testing for unit roots and co-integrations we have chosen to use a probability value of 0.10 in this study, which is an appropriate level of significance for use with small sample sizes such as that involved here. Table 1 reports unit root tests for the series of $TINV$ and GDP variables. The Phillips-Perron test provides the formal test for unit roots and stationarity in this study. As shown in Table 1, the Phillips-Perron values of all the variables are larger than the critical value of -10.2 at the 10% level. This indicates that the series of all the variables are non-stationary and thus any causal inferences are invalid. However, non-stationarity can be rejected for the series of all the variables at the 10% level when first-differenced data are used. Hence, the Granger causality models are estimated with first-differenced data.

[Insert Table 1 about here]
[Insert Table 2 about here]

As indicated, the basic idea behind co-integration is to test whether a linear combination of two individually non-stationary time series is itself stationary.

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[4] In January 2001, US$1 is approximately equal to 1300 Korean won.

Table 2 reports co-integration test for the series of *TINV* and *GDP*. As shown in the table, the Engle-Granger values are larger than the critical value of −3.24 at the 10% level for all cases. Evidence in this study indicates that the integrated variables have no inherent co-movement tendency over the long run. Thus, we conclude that telecommunications investment and GDP are not co-integrated. As stated previously, if the series of two variables are non-stationary and the linear combination of them is non-stationary, then standard Granger causality test rather than error-correction modeling should be employed. Therefore, the standard Granger causality test is appropriate, as shown in equations (1)-(4).

3.2 Results from Hsiao's version of the Granger causality tests

The results from Hsiao's version of the Granger causality tests are presented in Table 3 with F-values computed under the null hypothesis of no causality. As stated above, if $FPE(l_{11}^*, l_{12}^*) < FPE(l_{11}^*)$, then telecommunications investment Granger-cause economic growth. As illustrated in the table, it reveals that for the GDP equation, since $8.98 \times 10^{25} > 4.24 \times 10^{25}$, we cannot reject the hypothesis that telecommunications investment Granger-causes GDP. This means that the inclusion of past values of telecommunications investment in the GDP equation provides a better explanation of current values of GDP than when excluded. The result is further corroborated by the F-value (36.41), as shown in the third column of Table 3, which indicates that telecommunications investment significantly affects economic growth at the 1% level.

[Insert Table 3 about here]

Conversely, for the telecommunications investment equation, as indicated in Table 3, since $5.27 \times 10^{23} > 4.34 \times 10^{23}$, we conclude that GDP Granger-cause telecommunications investment. This implies that the inclusion of past values of GDP in the telecommunications investment equation provides a better explanation of current values of telecommunications investment than when excluded. The result is further confirmed by the F-value (8.52), as shown in Table 3, which reveals that economic growth affects telecommunications investment at the 1% significance level. To sum up, both *TINV* in GDP equation and *GDP* in telecommunications investment equation are statistically significant at the 1%

level, meaning that there is bi-directional causality between telecommunications investment and economic growth.

4. Summary, policy implications and conclusions

The purpose of this study was to test for Granger causality between telecommunications investment and economic growth for South Korea. Causality tests were performed using recently developed techniques in the time series literature and adapted in a framework where both traditional and additional channels of causality could be exposed. In summary, time series properties of the data were analyzed by way of unit root and co-integration tests before applying Granger's causality tests and several models were estimated to test for the direction of Granger causality. The findings of this paper are consistent with earlier researches (Cronin et al., 1991, 1993; Madden & Savage, 1998). Moreover the paper has brought evidence from a developing country, South Korea, in the relationship between telecommunications investment and economic growth as well as the direction of causality. These are interesting features of this paper.

We found that causality runs from telecommunications investment to economic growth with feedback. In other words, the existence of bi-directional causality between telecommunications investment and economic growth was detected. The study finding of bi-directional Granger causality or feedback between telecommunications investment and economic growth has a number of implications for policy analysts and forecasters in South Korea.

A high level of telecommunications investment leads to high level of economic growth. The telecommunications investment is the initial receptor of an exogenous impact and the equilibrium is restored through adjustment in the real income variable. This implies that telecommunications infrastructure shortage may restrain the economic growth in South Korea. Increasing economic growth requires enormous telecommunications investment, though there are many other factors contributing to economic growth, and telecommunications is but one part of it. In order not to adversely affect economic growth, efforts must be made to encourage government and industry to increase telecommunications investment. A policy for increasing telecommunications investment, therefore, likely to enhance economic growth for South Korea. In pursuit of continuing economic growth, South Korea will need to put more efforts into increasing telecommunications investment when implementing national information infrastructure as a strategy toward advanced development in the long haul. Thus, this study generates confidence in decisions to invest in the telecommunications infrastructure. Furthermore, as implied by Wang (1999), the payoff effect of telecommunications investment on economic growth can be achieved only through a robust national telecommunications infrastructure that supports telecommunications adoption and applications.

Moreover, this study lends support to the argument that an increase in real income, *ceteris paribus*, gives rise to telecommunications investment. Growth results in a higher proportion of national income spent on telecommunications services and stimulates further telecommunications investment. Intuitively, increased economic growth requires enormous telecommunications investment.

In summary, the principal finding is that feedback systems rather than unidirectional causality appear to exist in South Korea. For the newly industrializing countries such as South Korea in general, telecommunications infrastructure is an important ingredient of economic growth. Production in industries such as manufacturing, construction and transportation demands a substantial amount of telecommunications infrastructure. Consequently, increased telecommunications investment directly affects economic growth. Additionally, an increase in real income also influences telecommunications investment, which in turn boosts economic activity.

While causal linkages between telecommunications investment and economic growth our analysis conclusively demonstrates and the implications of the results may be unique for South Korea, it should be stressed that the techniques employed in this study can be readily applied to time series data from other countries and extended to other multivariate systems where telecommunications investment and real income are exposed to be determined by other economic factors such as net fixed capital stock, employment, exports etc. Furthermore, such an analysis could uncover the structural channels by which real income and telecommunications investment are inherently causal.

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Table 1.
Unit-root tests

Variables	Phillips-Perron values	
	Levels	First differences
GDP	−2.20[3]	−11.01[2]*
TINV	1.06[9]	−31.30[9]***

* and *** denote significance of the test statistic at the 10 and 1 % level of significance, respectively. The critical values of the Phillips-Perron statistic at the 10 and 1% levels are approximately −10.2 and −17.2, respectively, see Fuller (1976, p. 371). The number inside the brackets is the optimum lag determined using Akaike's information criterion described in Pantula et al. (1994).

Table 2.

Co-integration tests

Regressions	Engle-Granger values
GDP on *TINV*	−2.15[3]
TINV on *GDP*	−2.70[9]

The critical value of the Engle-Granger statistic at the 10% level is approximately −3.24, see Fuller (1976, p. 373). The number inside the brackets is the optimum lag determined using Akaike's information criterion described in Pantula et al. (1994).

Table 3.

Granger's causality tests between GDP and telecommunications investment

Regressions	FPE[a]	F-value
The GDP equation:		
$\Delta GDP_t = \alpha_{11} + \sum_{i=1}^{1} \beta_{11i} \Delta GDP_{t-i} + u_{11t}$	8.98×10^{25}	36.41***
$\Delta GDP_t = \alpha_{12} + \sum_{i=1}^{1} \beta_{11i} \Delta GDP_{t-i} + \sum_{j=1}^{1} \beta_{12j} \Delta TINV_{t-j} + u_{12t}$	4.24×10^{25}	
The telecommunications investment equation:		
$\Delta TINV_t = \alpha_{21} + \sum_{i=1}^{1} \beta_{21i} \Delta TINV_{t-i} + u_{21t}$	5.27×10^{23}	8.52***
$\Delta TINV_t = \alpha_{22} + \sum_{i=1}^{1} \beta_{21i} \Delta TINV_{t-i} + \sum_{j=1}^{1} \beta_{22j} \Delta GDP_{t-j} + u_{22t}$	4.34×10^{23}	

[a] FPE represents Akaike's (1969) final prediction error.

*** denotes significance of the test statistic at the 1% significance level.