Public Investment and Economic Growth in the Three Little Dragons: Evidence from Heterogeneous Dynamic Panel Data

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ABSTRACT

Although the investment–growth relationship in the NIEs has been studied rather extensively, the casual connection between public capital and economic growth has not yet been fully explored. This paper makes a novel attempt to study the interactions among these macroeconomic variables with the help of 1971-2000 heterogeneous dynamic panel data from Korea, Singapore, and Taiwan. The premise of this study is that public spending may contribute to economic growth in different ways. We explore this using a variety of econometric techniques. The analysis suggests that both public and private investment and public consumption have a long-term dynamic impact on economic growth in all the countries of our sample and in a panel of sample countries. The pair-wise analysis shows bidirectional causality between public investment and economic growth, and the homogeneous non-causality hypothesis suggests that non-causality results are completely homogeneous in a small sample of these mentioned countries.

Key Words: Public investment, economic growth, panel unit root test, panel data. **JEL classification**: H54, E62, C32.

1. INTRODUCTION

The paper sets out to investigate whether there exists a long-term dynamic relationship between public investment and economic growth in the East Asian NIEs (popularly called "Little Dragons" because they are small countries with unprecedented growth rate), which include Singapore, Taiwan, and Korea. The principal motivation is that, although the debate on the link between public investment and economic growth is age-old, three issues still remain unresolved. First is the issue of whether a permanent increase in public investment will induce a temporary or permanent increase in economic growth. Second is the recognition that the growth-effect of public investment depends on the relative marginal productivities of public and private capital. Third, the effect of public investments on economic growth also depends on how the increased spending is financed. This study is important because, using a sample of three East Asian countries, it seeks to bridge the knowledge gap about the effects of public investment on economic growth. It is also important because it employs more superior panel data techniques to elaborate on the long-term dynamic relationship.

We investigate these issues empirically in this paper. To do so, we estimate the dynamic long-term relationship between public investment, economic growth, private investment, and public consumption for three East Asian countries during the period 1971-2000. Further, we estimate any causal relationship between public investment and economic growth by using Granger-Causality test on panel data and on individual country data as well.

The rest of this paper is organized as follows. Section 2 presents a brief study of previous empirical studies. Section 3 provides data and methodology. Empirical findings are discussed in Section 4, and the main conclusions are stated in Section 5.

2. PREVIOUS EMPIRICAL STUDIES

A large body of previous empirical literature examines whether public investment (or some component of it) makes a distinct contribution to economic growth. Barro [1991] examines the effect of public investment and public consumption expenditures on cross-country growth rates. After controlling for a number of variables, it was found that public investment has no significant effect on growth rates, whereas the rate of economic growth is negatively related to the share of government consumption expenditure. Canning and Fay [1993] and Easterly and Rebelo [1992] use panel data to investigate the contribution to economic growth of transportation networks. A key finding of the study is a strong relationship between economic growth and public investment in transportation and communication. Devarajan et al. [1996] present evidence for 43 developing countries, which indicates that the share of total government expenditure (consumption plus investment) has no significant effect on economic growth. However, the authors found an important composition effect for government expenditure: that is, increases in the share of consumption expenditure have a significant positive effect on economic growth, whereas increases in the share of public investment expenditure have a significant negative effect. The negative effect also holds for each of the major components of public investment, including transportation and communication. This leads to the somewhat surprising prescription that governments in developing countries would be better advised to switch public resources from investment goods to current consumption.

Pritchett (1996) suggests another explanation for the Devarajan et al. [1996] findings – the "white elephant" hypothesis. He argues that public investment in developing countries is often used for unproductive and inappropriate projects. As a consequence, the share of public investment can be a very poor measure of the actual increase in economically productive public capital. On the one hand, higher public investment raises the national rate of capital accumulation above the level chosen (in a presumed rational fashion) by private sector agents; thus, public capital spending may crowd out private expenditures on capital goods on an ex-ante basis as individuals seek to re-establish an optimal inter-temporal allocation of resources. On the other hand, public capital – particularly infrastructure capital such as highways, water systems, sewers, and airports – is likely to bear a complementary relationship with private capital in the private production technology. Thus, higher public investment may raise the marginal productivity of private capital and thereby "crowd in" private investment.

Public investment has to be a source of endogenous growth. Under the hypothesis of balanced exogenous growth, public spending in the long run does not affect economic growth [King et al., 1991]. In an endogenous-growth economy, output follows a stochastic trend, and permanent policy changes have long-term consequences for the growth of output, whereas temporary policy changes have long-term consequences for the level of output [Jones, 1995; Kocherlakota and Yi, 1996; Evans et al., 1994; and Karras, 1999].

In the case of endogenous growth, demand-side effects of increased public spending or crowding-out effects from the way public spending is financed may have long-term effects on output levels. The impact of changes in public investment may vary with the level of public investment. Barro [1990] specifies an endogenous-growth model, which incorporates productive public spending (e.g., public investment financed by lump-sum taxes) into the production function, and he derives a growth-maximizing spending share. The relationship between public spending and growth depends on the current spending level; it is positive (negative) if public spending is below (above) the growth-maximizing share. Therefore, only when public investment is below its growth-maximizing share will additional public investment increase growth. The government spending has to take into account the marginal effects of different types of public spending. The fact that public investment affects output positively does not imply that increases in public investment represent an effective growth strategy.

A balanced growth strategy relies on several prerequisites. Investment in high-speed broadband telecommunication is required for businesses and institutions (e.g., universities, hospitals) to function efficiently and for individuals to communicate. Good quality transportation systems are needed to move people and goods rapidly and safely between towns and cities. Finally, there is a common need for investment in education. There is a role for government in promoting balanced growth. Government as an employer can foster balanced growth through the decentralized provision of public services. Another approach would be to focus on supporting community economic development (CED), including the provision of capital financing.

As is evident from the above discussion, the question of whether additional public investment is an effective policy strategy depends primarily on the nature of the growth process of the economy, as well as the levels of public investment and other types of public spending. A reasonable strategy for evaluating an economy's fiscal policy would be to analyze the effects of an increase in public investment on the overall economy – both without changing other budget components and with offsetting an increase by an equivalent reduction in public consumption.

3. METHODOLOGY AND DATA

The sample covers three East Asian countries over the period 1970-2000. Data for this study was compiled by collecting information from World Development Indicators CD-ROM (2001), by World Bank. Our study includes the following three East Asian countries: Korea, Singapore, and Taiwan. For each of the countries, we specify a four-variable model that includes public investment (GI), public consumption (GC), private investment (PI), and growth rate of gross domestic product (GDPG).

We take GDP growth rate as a measure of economic growth, but express public investment, public consumption, and private investment as ratios of GDP (GI/GDP, GC/GDP and PI/GDP). We express all variables in logarithms multiplied by 100. This choice of variables allows us to focus on the effects of public spending on economic growth. The inclusion of private investment enables us to account for two phenomena. First, private investment may enhance growth if it – as proposed by neoclassical theory – complements public investment. Second, crowding-out of private investment may however, reduce or offset growth.

Within this framework, we can investigate the dynamics of public and private investment and the consequences of reallocations between public consumption and investment. To test the long-term effects of changes in different types of public spending, we used a co-integration approach, which is particularly suitable for examining the role of public investment policies in an economy. For the comprehensive analysis, we further extended the study to test and identify the direction of causality. For this purpose, we conducted the Granger causality test on individual country data as well as on panel data.

3.1. Estimation Techniques

To examine the stationarity properties of the individual time series, we employ the unit root-tests of Phillips and Perron [1988], the augmented Dickey-Fuller Test [Dickey and Fuller, 1979], as well as the Kwiatkowski-Phillips-Schmidt-Shin Test [Kwiatkowski, Phillips, Schmidt, and Shin, 1992]. In neoclassical growth models, economic growth is exogenously determined by the rate of technological progress. Moreover, as King et al. [1991] show, in a stochastically driven, balanced growth economy, three ratios have to be stationary. In this case, the economy can be described by a common trend and three co-integration relationships. To test for balanced growth, we investigate for each country whether co-integration relationships exist among the four time series. We use the Johansen [1988, 1991] approach, now familiar from the theory of co-integration. We use the pair-wise Granger causality test to detect the causal relationship between two series as well as to identify the direction of such causality.

3.2. Panel Unit Root Test

Pesaran and Shin (1997) proposed a test for random walk residuals in a dynamic model with fixed effects. They assumed that both N and T tend to infinity. The model is

$$y_{it} = \rho_i y_{it-1} + z'_{it}\gamma + u_{it}, \qquad i = 1,...,N; t = 1,...,T \tag{1}$$

where z_{it} is the deterministic component and u_{it} is a stationary process. z_{it} could be zero, one, the fixed effects, μ_i, or fixed effect as well as a time trend, t. ρ_i is a vector of the autoregressive coefficient, and γ is a matrix of coefficients associated with the deterministic component (z'_{it}).

Im, Pesaran, and Shin [1997] (IPS) allowed for a heterogeneous coefficient of y_{it-1} and proposed an alternative testing procedure based on averaging individual unit root test statistics. IPS suggested an average of the augmented DF (ADF) tests when u_{it} is serially correlated with different serial correlation properties across cross-sectional units; i.e., $u_{it} = \sum_{j=1}^{pi} \varphi_{ij} u_{it-j} + \varepsilon_{it}$. Substituting this u_{it} in (1), we get:

$$y_{it} = \rho_i y_{it-1} + \sum_{j=1}^{pi} \varphi_{ij} \Delta_{it-j} + z'_{it}\gamma + \varepsilon_{it} \tag{2}$$

The null hypothesis is:
H_0: $\rho_i = 1$
for all *i,*
and the alternative hypothesis is:
H_0: $\rho_i < 1$
for at least one *i*.
The IPS *t*-bar statistic is defined as the average of the individual ADF statistics as

$$\bar{t} = \frac{1}{N}\sum_{t=1}^{N} t_{\rho_i} \tag{3}$$

where $t_{\rho i}$ is the individual t-statistic of testing $H_0 : \rho_i = 1$ in (2). As $T \rightarrow \infty$,IPS assumed that t_{iT} are *iid* and have finite mean and variance. Then:

$$\frac{\sqrt{N}\left(\frac{1}{N}\sum_{i=1}^{N} t_{iT} - E\left[t_{iT}\middle|\rho_i = 1\right]\right)}{\sqrt{Var\left[t_{iT}\middle|\rho_i = 1\right]}} \Rightarrow N(0,1)$$

as $N \rightarrow \infty$ by the Lindeberg – Levy Central Limit theorem. Hence:

$$t_{IPS} = \frac{\sqrt{N}\left(\bar{t} - E\left[t_{iT}\middle|\rho_i = 1\right]\right)}{\sqrt{Var\left[t_{iT}\middle|\rho_i = 1\right]}} \Rightarrow N(0,1) \tag{4}$$

as $T \rightarrow \infty$ followed by $N \rightarrow \infty$ sequentially. The values of $E\left[t_{iT}\middle|\rho_i = 1\right]$ and $Var\left[t_{iT}\middle|\rho_i = 1\right]$ have been computed by IPS via simulations for different values of T and p'_is.

3.3. Panel Co-Integration

Pedroni (1997a) proposed several tests for the null hypothesis of co-integration in a panel data model that allows for considerable heterogeneity. To perform a test of co-integration on panel data, we choose a non-parametric statistic that is analogous to the familiar Phillips and Perron rho-statistic [Pedroni (1997a)].

We can compute Phillips and Perron rho-statistics by performing the following steps:

1. Estimate the panel co-integration regression (5), making sure to include any desired intercepts, time trends, or common time dummies in the regression, and to collect the residuals $\hat{e}_{i,t}$ for later use.

$$y_{i,t} = \alpha_i + \delta_i t + \beta_{1i} x_{1i,t} + \beta_{2i} x_{2i,t} + ... + \beta_{Mi} x_{Mi,t} + e_{i,t} \quad (5)$$

for $t = 1, \ldots, T$; $i = 1, \ldots, N$; $m = 1, \ldots, M$

where T refers to the number of observations over time, N refers to the number of individual members in the panel, and M refers to the number of regression variables. Since there are N different members of the panel, we can think of N different equations, each of which has M regressors. Notice that the slope coefficients β_{1i}, β_{2i}, ..., β_{Mi}, are permitted to vary across individual members of the panel. The parameter a_i is the member-specific intercept, or fixed-effects parameter, which of course is also allowed to vary across individual members.

2. Difference the original series for each member, and compute the residuals for the differenced regression

$$\Delta y_{i,t} = b_{1i} \Delta x_{1i,t} + b_{2i} \Delta x_{2i,t} + ... + b_{Mi} \Delta_{Mi,t} + \eta_{i,t}.$$

3. Calculate $\hat{L}^2_{1li}$ as the long-term variance of $\hat{n}_{i,t}$ using any kernel estimator, such as the Newey-West [1987]) estimator.

4. Using the residuals $\hat{e}_{i,t}$ of the original co-integrating regression, estimate $\hat{e}_{i,t} = \hat{\gamma}_{i,t-1} + \hat{u}_{i,t}$, and use the residuals to compute the long-term variance of $\hat{u}_{i,t}$, denoted $\hat{\sigma}^2_i$. The term $\hat{\lambda}_i$ can then be computed as $\hat{\lambda}_i = \frac{1}{2}\left(\hat{\sigma}^2_i - \hat{s}^2_i\right)$ where $\hat{s}^2_i$ is just the simple variance of $\hat{u}_{i,t}$. Notice that these are the same as the usual correction terms that enter into the conventional single-equation Phillips-Perron tests.

5. Using each of these parts, construct Phillips and Perron rho-statistics:

Panel ρ-Statistic:

$$T\sqrt{N} Z_{\hat{\rho}N,T-1} \equiv T\sqrt{N}\left(\sum_{i=1}^{N}\sum_{t=1}^{T} \hat{L}^{-2}_{1li} \hat{e}^2_{i,t-1}\right)^{-1} \sum_{i=1}^{N}\sum_{t=1}^{T} \hat{L}^{-2}_{1li}\left(\hat{e}_{i,t-1} \Delta\hat{e}_{i,t} - \hat{\lambda}_i\right) \quad (6)$$

where,

$$\hat{\lambda}_i = \frac{1}{T}\sum_{s=1}^{k_i}\left(1 - \frac{s}{k_i + 1}\right)\sum_{t=s+1}^{T} \hat{\mu}_{i,t}\hat{\mu}_{i,t-s}$$

$$\hat{L}^2_{1li} = \frac{1}{T}\sum_{t=1}^{T}\hat{\eta}^2_{i,t} + \frac{2}{T}\sum_{s=1}^{k_i}\left(1 - \frac{2}{k_i + 1}\right)\sum_{t=s+1}^{T}\hat{\eta}_{i,t}\hat{\eta}_{i,t-s}$$

6. Apply the appropriate mean and variance adjustment terms (See Pedroni, 1999) to standardize the panel ρ-statistic.

3.4. Granger Causality in Panel Data Set

Let us consider a time-stationarity VAR representation, adapted to a panel data context. For each individual *i,* we have $\forall t \in [1,T]$:

$$y_{i,t} = \sum_{k=1}^{p} \rho^{(k)} y_{i,t-k} + \sum_{k=0}^{p} \beta_i^{(k)} x_{i,t-k} + v_{i,t} \qquad (7)$$

with $p \in N^*$ and $v_{i,t}=\alpha_i+\varepsilon_{i,t}$, where $\varepsilon_{i,t}$ are *i.i.d.* $(0,\sigma_\varepsilon^2)$. Contrary to Winhold (1996) and Nair-Reichert and Weinhold (2001), we assume that the autoregressive coefficients $\rho^{(k)}$ and the regression coefficients slopes $(\beta_i^{(k)})$ are constant $\forall k \in [1,p]$. We also assume that parameters $\rho^{(k)}$ are identical for all individuals, whereas the regression coefficients slopes $(\beta_i^{(k)})$ could have an individual dimension. Initial conditions $(y_{i,-p}, \ldots, y_{i,0})$ and $(x_{i,-p}, \ldots, x_{i,0})$ of both individual processes $y_{i,t}$ and $x_{i,t}$ are given and observable.

The test procedure has three main steps – the HNC hypothesis test, the HC hypothesis test, and the HENC hypothesis test.

3.4.1. HNC Hypothesis Test

The first step consists in testing the homogenous non-causality hypothesis (HNC). For that, we have to test whether the regression slope coefficients associated to $x_{i,t-k}$ are null for all individual i and all lag k. In order to test these Np linear restrictions, we compute the following Wald statistic:

$$F_{hnc} = \frac{(RSS_2 - RSS_1)/(Np)}{RSS_1/[NT - N(1+p) - p]} \qquad (8)$$

where RSS_2 denotes the restricted sum of squared residual obtained under H_0 and RSS_1 corresponds to the residual sum of squares of the model (7), while [NT-N(1+p)-p] are degrees of freedom in the unrestricted model.

If the realization of this statistic is not significant, the *homogenous non-causality* hypothesis is accepted. This result implies that the variable *x* is not causing *y* in all the *N* countries of the samples. The non-causality result is then totally homogenous and the testing procedure will go no further.

3.4.2. HC Hypothesis Test

If we reject the null hypothesis of non-homogenous causality (*HNC*), two configurations could appear. The first one corresponds to the overall causality hypothesis (*homogenous causality hypothesis, HC*) and occurs if all the coefficients β_i^k are identical for all lag *k* and are non-null. The second one, which is the more plausible, is that some coefficients β_i^k are different for each individual. Thus, after the rejection of the null hypothesis of *HNC*, the second step of the procedure consists in testing if the regression slope coefficients associated to $x_{i,t-k}$ are identical. This test corresponds to a standard homogeneity test. In order to test the *HC* hypothesis, we have to compute the following *F* statistic:

$$\boldsymbol{F_{hc}} = \frac{(RSS_3 - RSS_1)/[p(N-1)]}{RSS_1/[NT - N(1+p) - p]} \tag{9}$$

where RSS_3 corresponds t the realization of the residual sum of squares obtained in model (7) when one imposes the homogeneity for each lag *k* of the coefficients associated to the variable $x_{i,t-k}$.

For large samples, if the F_{hc} statistic with $p\ (N-1)$ and $NT-N(1+p)-p$ degrees of freedom is not significant, the *homogenous causality hypothesis* is accepted. This result implies that the variable *x* is causing *y* in the *N* countries of the samples, and that the autoregressive processes are completely homogenous.

3.4.3. HENC Hypothesis Test

If the *HC* hypothesis is rejected, it implies that the process is non-homogenous and that no homogenous causality relationships can be found. However, it does not imply the lack of any causality relationships between the two variables. It may be possible that, for one individual at least, there exists such a relationship. In this case, we get a non-homogenous causality configuration. So, the third step of the procedure consists in testing the heterogeneous non-causality hypothesis (HENC). We propose here to test this last hypothesis with two nested tests. The first test is an individual test realized for each individual.

$$F_{henc}^{i} = \frac{(RSS_{2,i} - RSS_1)/p}{RSS_1/[NT - N(1+2p) + p]} \tag{10}$$

where $RSS_{2,i}$ corresponds to the realization of the residual sum of squares obtained in model (7) when one imposes the nullity of the *k* coefficients associated to the variable $x_{i,t-k}$ only for the individual *i*. These *N* individual tests allow us to identify the individual for which there are no causality relationships.

A second test of the procedure consists in testing the joint hypothesis that there are no causality relationships for a subgroup of individuals. One solution to test the *HENC* hypothesis is to compute the Wald statistic:

$$F_{henc} = \frac{(RSS_4 - RSS_1)/(n_{nc}p)}{RSS_1/[NT - N(1+p) - n_c p]} \quad (11)$$

where RSS_4 corresponds to the realization of the residual sum of squares obtained in model (7) when one imposes the nullity of the k coefficients associated to the variable $x_{i,t-k}$ for the n_{nc} individuals of the I_{nc} subgroup.

If the *HENC* hypothesis is accepted, it implies that there exists a subgroup of individual for which the variable x does not cause the variable y. This hypothesis can be analyzed as the consequence of the heterogeneity of the data-generating process. The causality relationship occurs only for a subgroup of individual. On the contrary, if the *HENC* hypothesis is rejected, it implies that there exists causality relationships between x and y for all individuals of the panel, but the data generating process stills heterogeneous. Then, we get the HEC hypothesis.

3.5. Diagnostic and Stability Tests

Diagnostic tests for serial correlation, normality, heteroscedasticity, and functional form are considered, and results are shown in Table 2 in Appendix A. These tests show that the short-term model passes through all diagnostic tests in the first stage. The results indicate that there is no evidence of auto-correlation and that the model passes the test for normality, proving that the error term is normally distributed. The functional form of the model is well specified, but white heteroscedasticity exists in the model. The presence of heteroscedasticity does not affect the estimates, and the time series in the equation are of mixed order of integration; it is natural to detect heteroscedasticity [Shrestha, 2005].

Finally, when analyzing the stability of the long-term coefficients together with the short-term dynamics, we apply the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMsq). According to Pesaran and Shin [1999], the stability of the estimated coefficient of the error correction model should also be empirically investigated.

Graphical representations of CUSUM and CUSUMsq are shown in figures 1 and 2 in Appendix B. Following Bahmani-Oskooee [2004], the null hypothesis (i.e., that the regression equation is correctly specified) cannot be rejected if the plot of these statistics remains within the critical bounds of the 5% significance level. As is clear from figures 1 and 2, the plots of both the CUSUM and the CUSUMsq are within the boundaries; hence, these statistics confirm the stability of the long-term coefficients of regressors, which affect the inequality in the country. The stability of selected ARDL model specification is evaluated using the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMsq) of the recursive residual test for the structural stability [see Brown et al., 1975]. The model appears stable and correctly specified, given that neither the CUSUM nor the CUSUMsq test statistics exceed the bounds of the 5% level of significance (see figure given in Appendix B).

4. EMPIRICAL FINDINGS

4.1. Testing Non-Stationarity and Co-Integration

The preliminary step in our analysis is concerned with establishing the degree of integration of each variable as sample countries. For this purpose, we test for the existence of a unit root in the level and first difference of each of the variables in our sample, using the Augmented Dickey Fuller (ADF) unit root test, the Phillips-Perron (PP) unit root test, and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. The ADF, PP, and KPSS statistics are calculated with a constant and with a constant plus a time trend, respectively. A summary of these test results is reported in Table 1(a), 1(b), and 1(c) in Appendix A. Results show that each of the variables is a non-stationary process in level form, but stationary in their first differences.

Given the common integrational properties of the variables under consideration, it is possible to use multivariate co-integration methodology developed by Johansen [1988] in order to test for the existence of a stable relationship between economic growth, public and private investment, and public consumption. The results from the Johansen co-integration analysis are summarized in Table 3 in Appendix A, where both the max and trace statistics examine the null hypothesis of non-co-integration against the alternative of co-integration. The maximal eigen value and trace statistics for all sample countries indicate the existence of long-term equilibrium relationships among the variable under consideration, by rejecting the null hypothesis of non-co-integration.

4.2. Testing Pair-Wise Granger Causality Country by Country

The results of pair-wise causality analysis of sample countries are reported in tables 4(a) and 4(b) in Appendix A. The results clearly indicate that economic growth was caused by public investment in all the sample countries except Singapore, whereas public investment was significantly caused by economic growth in all sample countries. Therefore, there exists bi-directional causality between economic growth and public investment. The results show that private investment was caused by economic growth in all the sample countries, whereas economic growth was caused by private investment in all countries except Singapore. A two-way causal relationship exists between private investment and economic growth in all sample countries except Singapore, where there is a one-way causal relationship between private investment and economic growth. The results also indicate that economic growth causes government consumption in all sample countries, whereas government consumption does not cause economic growth in the two sample countries, Singapore and Korea. Hence, the results provide strong evidence of the bi-directional causal relationship of economic growth and public and private investment.

5. DYNAMIC PANEL DATA RESULTS

5.1. Testing for Non-Stationarity and Co-Integration in Panel Data

In this section, we summarize the non-stationary panel data tests for unit roots and co-integration we have to use and offer some intuition behind the testing. The test of the null hypothesis of cointegration states that under the H_0 there exists a long-run relationship among the variables under consideration. The model allows for varying intercepts, trends and varying slopes and thus a cointegration test for heterogeneous cross-sections is applicable.

The first step in determining a potentially cointegrated relationship is to test whether the variables involved are stationary or non-stationary, i.e. whether the individual series contain unit roots. If all the variables are stationary, then traditional estimation methods can be used to estimate the long-run relationship among the variables, in this case economic growth, public and private investment and public consumption. Pesaran and Shin (IPS) (1997) first presented the test we use for stationarity. IPS unit root results are reported in Table 4 in Appendix A. The results indicate that public and private investment (GI and PI) variables with and without trend rejected the null hypothesis of non-stationarity at lag value p=0, 1 and 2. The variable economic growth (GDP) in both cases with and without trend has a unit root at p=0 and 1, whereas the government consumption variable has a unit root at p=0 and 1 in case of without time trend and failed to reject the hypothesis at p=1 and 2 in case of with time trend. According to these findings, we have evidence of the existence of stationarity in most of the cases.

The existence of a long-term relationship is examined using Panel ρ-statistic, reported in Table 6 in Appendix A. For the panel of three East Asian countries, the estimated standardized panel ρ-statistic provides a strong evidence of a long-term dynamic relationship among the variable under consideration, by rejecting the null hypothesis of non-co-integration.

5.2. Testing Granger Causality in Panel Data

In this section, we examine Granger causality between economic growth and public investment, private investment and public consumption, and vice versa, for the panel of three East Asian countries. The first step of Granger causality in panel data, the F-test of homogeneous non-causality hypothesis, has performed for the lag order of one to five. The results of this test are reported in tables 7(a) and 7(b) in Appendix A. These results show that F-test is statistically insignificant in all cases (GI≠>GDP, PI≠>GDP, GC≠>GDP, GDP≠>GI, GDP≠>PI and GDP≠>GC), and the homogeneous non-causality hypothesis has been failed to reject, irrespective of the choice of the lag order. The result implies that there is no evidence of causality between variables tested in a panel of sample countries. The non-causality results are then totally homogeneous and the testing procedure will go no further.

6. CONCLUSIONS

In this paper, we have addressed an important topical issue; namely, the dynamic impact of public investment on economic growth in a panel of East Asian countries. There are some extensions of the present framework that we think are worth pursuing. The first and more immediate one would be to include private investment in the model because it enhances growth as proposed by neoclassical theory, and it complements public investment. The crowding-out effect of private investment may reduce or offset growth. A second extension would be to include public consumption. In the present framework, when we investigate the dynamics of public investment, the reallocation of public consumption may positively affect growth.

The premise of this study is that public spending may contribute to economic growth in different ways. To explore this, we use a variety of econometric techniques. The analysis suggests that both public and private investment and public consumption have a long-term dynamic impact on economic growth, in all the countries of the sample and in the panel of sample countries. The panel causality analysis shows no evidence of causal relationship between variables under discussion, and the homogeneous non-causality hypothesis suggests that non-causality results are completely homogeneous in a small sample of East Asian countries. The results of the diagnostic and stability tests indicate that the model passed all the diagnostic tests. The error term was normally distributed. The CUSUM and CUSUMsq stability tests show that the estimated coefficients of the error correction model are stable. This provides strong evidence that little dragon's economic data have no structural breakpoint, which addresses the above conclusion more comprehensively.

APPENDIX A: TABLES

Table 1(a). ADF Test for Unit Root

	GDP		GC		GI		PI	
	Constant	Constant and Trend	Con-stant	Constant and Trend	Constant	Constant and Trend	Con-stant	Con-stant and Trend
A) Level								
Singapore	4.30	0.88	2.35	0.03	0.59	-1.27	0.61	-1.26
Korea	+2.06	-1.52	0.02	-1.95	-0.78	-2.38	-0.64	-2.41
Taiwan	1.29	-1.18	0.86	-1.39	-1.32	-2.44	-1.31	-2.43
B) Difference								
Singapore	-5.47*	-5.38*	-4.56*	-4.77*	-4.40*	-4.91*	-4.39*	-4.91*
Korea	-4.25*	-4.29*	-5.99*	-6.38*	-4.16	-4.27**	-4.09*	-4.13**
Taiwan	-3.99*	-3.90***	-4.23*	-4.10***	-3.50	-3.30***	-4.82*	-4.28**

Table 1(b). PP Test for Unit Root

	GDP		GC		GI		PI	
	Constant	Constant and Trend	Constant	Constant and Trend	Constant	Constant and Trend	Constant	Constant and Trend
A) Level								
Singapore	8.73	+1.35	3.66	0.71	0.72	-1.73	0.75	-1.72
Korea	2.57	-1.39	0.45	-1.81	-0.51	-2.05	-0.64	-1.98
Taiwan	-1.71	-1.15	1.05	-1.86	-1.27	-2.13	-1.26	-2.13
B) Difference								
Singapore	-10.83*	-10.68*	-7.13	-7.33*	-6.94*	-8.03*	-6.93*	-8.03
Korea	-4.82*	-5.86*	-8.30***	-8.67*	-3.82*	-3.74**	-3.54**	3.47***
Taiwan	-4.07**	-4.54*	-5.66*	-5.67*	-4.45*	-4.36*	-4.47*	-4.38*

Table 1(c). KPSS Test for Unit Root

	GDP		GC		GI		PI	
	Constant	Constant and Trend	Con-stant	Constant and Trend	Constant	Constant and Trend	Con-stant	Con-stant and Trend
A) Level								
Singapore	6.40	1.57	2.85	1.04	0.87	-1.31	0.78	-1.13
Korea	2.14	-1.42	0.02	-1.32	-0.68	-2.35	-0.67	-2.54
Taiwan	1.37	-1.22	0.33	-1.14	-1.24	-2.48	-1.35	-2.67
B) Difference								
Singapore	-5.24*	-5.29*	-4.43*	-4.63*	-4.27*	-4.78*	-4.26*	-4.86*
Korea	-4.21*	-4.18*	-5.87*	-6.27*	-4.09	-4.19**	-4.11*	-4.09**
Taiwan	-3.87*	-3.88***	-4.19*	-4.06***	-3.47	-3.43***	-4.74*	-4.18**

Key: * Statistics those are significant at 1% level.
** Statistics those are significant at 5% level.
*** Statistics those are significant at 10% level.

Table 2. Lag Length Selection

Order of Lag	Schwartz Bayesian Criteria	F-test Statistics
1	-17.62182	2.627
2	-16.17425	5.89

Short-run Diagnostic Test-Statistics:

Serial Correlation LM, F = 1.64 (0.212)
Normality J-B Value = 1.60 (.4487)
Heteroscedesticity Test, F = 2.65 (0.0296)
Ramsey RESET Test, F = 0.601935 (0.445746)

Table 3. FIML Johansen's Co-integration Test

(a) Trace Statistics:

Countries	GDP, GC, GI, PI							
	Null Trace							
	R = 0	5% Critical Value	R < = 1	5% Critical Value	R < = 2	5% Critical Value	R < = 3	5% Critical Value
Singapore (a)	76.71	47.21	40.96	29.68	22.95	15.41	7.48	3.76
Korea (b)	81.63	54.64	45.29	34.55	26.37	18.17	8.13	3.74
Taiwan (b)	82.89	54.64	50.39	34.55	27.30	18.17	8.20	3.74

Key: a- Linear deterministic trend in the data
b- Quadratic deterministic trend in the data

(b) Maximum Statistics:

Countries	GDP, GC, GI, PI							
	Null Max. Eg, Value							
	R = 0	5% Critical Value	R < = 1	5% Critical Value	R < = 2	5% Critical Value	R < = 3	5% Critical Value
Singapore (a)	35.75	17.53	18.01	14.27	15.47	11.65	7.48	3.76
Korea (b)	36.34	20.09	18.92	14.62	18.24	14.43	8.13	3.74
Taiwan (b)	32.50	20.09	23.09	14.62	19.10	14.43	8.20	3.74

Key: a- Linear deterministic trend in the data
b- Quadratic deterministic trend in the data

Table 4(a). Granger Causality Country by Country

Null Hypothesis / Countries	GDP ≠> PI	GDP ≠> GI	GDP ≠> GC
Singapore	5.04*	5.02*	3.24**
Korea	6.27**	7.01*	2.83***
Taiwan	3.56**	3.54**	1.81

Key: * Significant at 1%.
** Significant at 5%.
*** Significant at 10%.

Table 4(b). Granger Causality Country by Country

Null Hypothesis / Countries	PI ≠> GDP	GI ≠> GDP	GC ≠> GDP
Singapore	0.95	0.95	0.43
Korea	7.08*	6.99*	2.16
Taiwan	3.02***	3.01***	0.74

Key: * Significant at 1%.
** Significant at 5%.
*** Significant at 10%.

Table 5. IPS Unit Root Test

Series	IPS-Statistics	Inference
Without Time Trend		
P = 0		
GDP		
GC		
GI		
PI		
P = 1		
GDP	6.4767	Reject H_0 at 1%
GC	9.4986	Reject H_0 at 1%
GI	4.6044	Reject H_0 at 1%
PI	8.1523	Reject H_0 at 1%
P = 2		
GDP	2.7831	Reject H_0 at 1%
GC	2.8111	Reject H_0 at 1%
GI	6.7700	Reject H_0 at 1%
PI	7.7016	Reject H_0 at 1%
	0.5717	Fail to reject H_0
	1.3153	Fail to reject H_0
	4.0629	Reject H_0 at 1%
	4.9683	Reject H_0 at 1%
Without Time Trend		
P = 0		
GDP		
GC		
GI		
PI		
P = 1		
GDP	8.0970	Reject H_0 at 1%
GC	8.8019	Reject H_0 at 1%
GI	7.8418	Reject H_0 at 1%
PI	7.7437	Reject H_0 at 1%
P = 2		
GDP	4.3809	Reject H_0 at 1%
GC	1.6276	Fail to reject H_0
GI	6.0481	Reject H_0 at 1%
PI	5.9696	Reject H_0 at 1%
	1.1873	Fail to reject H_0
	0.3285	Fail to reject H_0
	6.1449	Reject H_0 at 1%
	6.7539	Reject H_0 at 1%

Without Time Trend
Critical Value at 1% = -2.18
Critical Value at 5% = -1.99
Critical Value at 10% = -1.88

With Time Trend
Critical Value at 1% = -2.79
Critical Value at 5% = -2.60
Critical Value at 10% = -2.51

Table 6. Panel Co-integration

<u>PANEL P-STATISTIC:</u>

$$T\sqrt{N}Z_{\hat{p}_{N,\frac{1}{T}}} = \frac{T\sqrt{N}\sum_{t=1}^{N}\left[\frac{\sum_{t=1}^{T}\left(\hat{e}_i^2, t-1\Delta\hat{e}_{i,t} - \lambda\right)}{\hat{L}_{11i}^2}\right]}{\sum_{i=1}^{N}\left[\frac{\sum \hat{e}i^2, t-1}{\hat{L}_{11i}^2}\right]}$$

$$= T\sqrt{N}\frac{\sum_{i-1}^{N}\Delta}{\sum_{i-1}^{N}B}$$

Countries	$\hat{\lambda}_i$	$\hat{L}_{11i}^2$	$\Sigma\left(\hat{e}_i^2, t-1\Delta\hat{e}_{i,t} - \hat{\lambda}_i\right)$	$\Sigma\hat{e}_i^2, t-1$
Singapore	-3.8510^{17}	$3.70\text{x}10^{19}$	$1.96\ \text{x}10^{21}$	$2.13\ \text{x}10^{21}$
Korea	2.8610^{17}	$6.54\text{x}10^{18}$	$-1.07\ \text{x}10^{20}$	$4.07\ \text{x}10^{20}$
Taiwan	6.8010^{18}	$9.07\text{x}10^{19}$	$-1.86\ \text{x}10^{21}$	$5.16\ \text{x}10^{21}$

Panel p-Statistic: –9.50

<u>Standardized Panel p-Statistic:</u>

Panel p Standardized $(Z_p) = \frac{X_N - \mu\sqrt{N}}{\sqrt{\upsilon}}$ => (0,1)

$(Z_p) = 3.09$

Critical Value of Normal Distribution at 10% = 1.645
Critical Value of Normal Distribution at 5% = 1.96

Table 7(a). F-Test Homogenous Non-Causality Hypothesis (F_{hnc}) for Panel of Sample Countries

No. of Lags	GDP ≠> PI	GDP ≠> GI	GDP ≠> GC
1	-0.0116	-0.0150	-0.0350
2	-0.0256	-0.0103	-0.0256
3	-0.0190	-0.0190	-0.0104
4	-0.0154	-0.0154	-0.0098
5	-0.0129	-0.0129	-0.0085

Table 7(b). F-Test Homogenous Non-Causality Hypothesis (F_{hnc}) for Panel of Sample Countries

No. of Lags	PI ≠> GDP	GI ≠> GDP	GC ≠> GDP
1	-0.3050	-0.0147	-0.3169
2	-0.2063	-0.2123	-0.0094
3	-0.1588	-0.0074	-0.1626
4	-0.1320	-0.0065	-0.1254
5	-0.1024	-0.0056	-0.1042

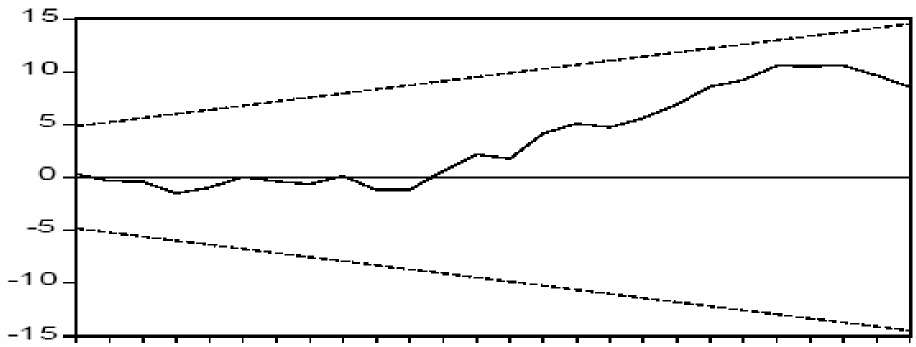
APPENDIX B: FIGURES

—— CUSUM of Squares ------ 5% Significance

The straight lines represent critical bounds at 5% significance level.

Figure 1

Plot of Cumulative Sum of Recursive Residuals

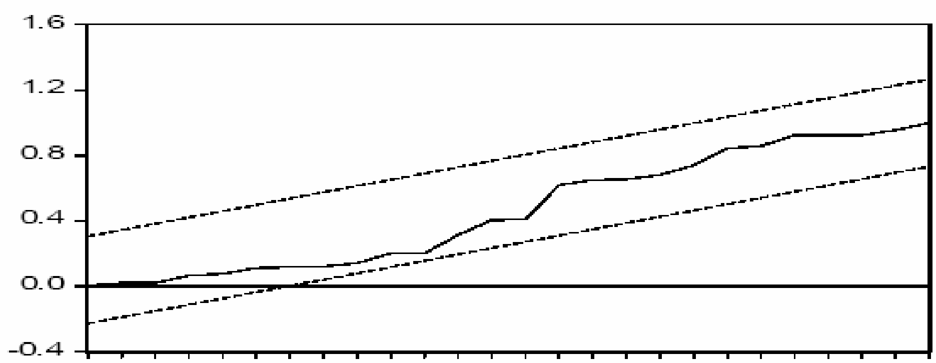


—— CUSUM of Squares ------ 5% Significance

The straight lines represent critical bounds at 5% significance level.

Figure 2

Plot of Cumulative Sum of Squares of Recursive Residuals



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