DOES PUBLIC R&D CROWD OUT PRIVATE R&D?
A NOTE FROM TAIWAN, ROC

YEMANE WOLDE-RUFAEL[*]

Camden Strategy Unit

This paper tests the cointegration and causal relationship between aggregate public R&D and private R&D for Taiwan for the period 1979-2007 using a newly developed cointegration test proposed by Pesaran *et al.* (2001) and using a modified version of the Granger causality test due to Toda and Yamamoto (1995). The paper finds a long run cointegrating relationship between public and private R&D and a bi-directional causality where they complement each other. The Government of the ROC should continue to invest not only to stimulate private R&D but also to enable the country to compete more globally in technology-intensive products.

Keywords: Taiwan, Public and Private R&D, Bounds Test, Causality, Impulse Response
JEL classification: C22, O32

1. INTRODUCTION AND OVERVIEW

The economic development achieved by Taiwan is the envy of all if not the substantial majority of developing countries. Within five decades, Taiwan has been transformed from a poor developing country to almost a developed one. To many students of the Taiwanese economy this exceptionally high growth and structural transformation is largely attributed to the 'mutually reinforcing dynamic interactions among exports, saving and investment' where the government played a crucial role in shaping this to happen (Akyüz and Gore (1996) and Akyüz *et al.* (1998)). Part of this strategy was to encourage and to promote R&D both private and public as a means of transforming Taiwan into a modern economy by moving away from labour-intensive to capital, human and technology intensive industries (see Chen *et al.* (2004), Chen (1999), and Mathews (2002)). To that end, the government fostered collaborative work not only between the government and private Taiwanese firms but also between Taiwanese and

foreign firms (Chen (1999) and Mathews (2002)). Developing science parks and attracting highly educated Taiwanese both nationally and internationally were part of the strategy of fostering technological progress and of making sure that the evolving comparative advantage of ROC moved towards highly skilled-and technologically-oriented industrial base (Chen (1999)). In the 1970s, with rising wages and a need to upgrade industry, the Government targeted higher technology, discouraged labour-intensive foreign direct investment (FDI) and favoured investments in automation, informatics and precision instruments. Indeed there is evidence to indicate that an increase in Taiwan's patent leads to increase in Taiwan's economic growth for long-run and short-run (Yang (2006)) indicating that Taiwan's fast economic growth may partly be attributed to the aggressive innovation policy pursued over the years (Yang (2006)).

The main driving force for increasing R&D came from the export orientation of the economy, combined with measures to reduce dependence on technology imports (UNCTAD (2003)). Taiwan's R&D expenditure has significantly increased since 1993 mainly in response to the enormous challenge facing the country from potential competitors and from other serious challenges including wage hikes and skilled labour shortages. Above all, it was widely recognised by the government that Taiwan's future development lies on a knowledge-based economy where technology was the driving force (Yang (2006)). To foster this knowledge-based economy an number of strategic measures were taken. The government began to make structural adjustments in order to raise the technological level of its firms, and to speed up the development of new high-tech industries (Lin (2001)). Under the government's guidance, Taiwanese industries have increased their R&D investment and have built a solid foundation for industrial development (Shyu and Chiu (2002)). In particular, the government brought forward infrastructure projects, implemented tax incentives, and created an investment environment that is more conducive to R&D activities Taiwan has followed public sector driven R&D (Nagano (2006)) and since the late 1990s this has made Taiwan one of the major producers of information-technology products in the world, obtaining a leading global market share in several key commodity categories (Fang *et al.* (2002)). In a number of technologically advanced industries Taiwan's manufacturing capacity is already competing successfully at the international level this has enhanced the strategic position of Taiwan in the global economy (Fang *et al.* (2002)). Taiwan has now graduated from imitation to innovation by building its indigenous technological capacity and raising the level of technology (Yang (2006)). Indeed, many students of the East Asian countries contend that the critical source of growth for these countries has been productivity growth resulting from learning, entrepreneurship and innovation where these countries not only adopted foreign technologies but they were also successful in the development of indigenous technologies (see Mahmood and Singh (2003)).

The purpose of this paper is to test whether public aggregate national R&D 'crowds in' or 'crowds out' private R&D in Taiwan using data for the period 1979-2007 by extending the debate in three methodological approaches. First, we test for cointegration using the autoregressive distributive lag (ARDL) approach to cointegration due to

Pesaran *et al.* (2001) which is capable of testing for the existence of a long-run relationship regardless of whether the underlying time data series are individually I(0), I(1) or mutually cointegrated. This procedure does not require knowledge of the order of integration or cointegration ranks of the variables under consideration before conducting tests for cointegration. Thus the ARDL procedure avoids the inherent limitations of testing for unit roots prior to testing for cointegration. The approach is particularly attractive when we are not sure whether the series are I(0) or I(1) as the procedure can be applied irrespective of the regressors are I(0) or I(1) or mutually cointegrated. An added bonus of this approach is that unlike other conventional tests for cointegration, it can be applied to studies that have small sample size such as our study with 29 observations (Narayan (2005)). Given the importance of establishing the relationship among the series, we want to ensure that our results are not contingent only on the ARDL approach to cointegration. Our strategy is also to compare results obtained from several of these tests and examine whether the preponderance of the evidence makes a convincing case for robust evidence. Therefore, to complement and check the robustness of the Pesaran *et al.* (2001) bounds approach, we have also used two additional long run tests, the dynamic ordinary least squares (DOLS) due to Stock and Watson (1993) and the fully modified ordinary least squares (FMOLS) due to Phillips and Hansen (1990). Secondly, the paper tests for causality using a modified version of the Granger causality test due to Toda and Yamamoto (1995) which is valid regardless of whether a series is I(0), I(1) or I(2), non-cointegrated or cointegrated of any arbitrary order. Thirdly, the paper attempts to quantify how much feedback exists from one series to the other using the recently developed generalized forecast error variance decomposition technique proposed by Pesaran and Shin (1998) which does not depend on the ordering of the variables. With the above in mind, the rest of the paper is structured as follows. In section 2 we briefly discuss the empirical literature. The methodology used is discussed in section 3, while the empirical evidence is presented in section 4. Concluding remarks are presented in section 5.

2.   THE RELATION BETWEEN PUBLIC AND PRIVATE R&D: BRIEF LITERATURE REVIEW

The relationship between private and public R&D investment has been a controversial issue in development economics and still continues to be a subject of heated debate. For some, public expenditure can have an adverse effect on growth through the 'crowding-out' of efficient and potentially profitable private. In contrast, others contend that public R&D investment complements or 'crowds in' private R&D investment by public R&D investing in ventures where private investment is shy to undertake. This provides the necessary infrastructure that is indispensable for the private sector to flourish. In this respect, civilian R&D expenditure funded through public agencies may generate social benefits in the form of knowledge and training spillovers

that cause positive external effects on the knowledge accumulation of the private sector (see David *et al.* (2000)). Leyden and Link (1991) propose that infra-technology provides the critical link that comes out as a result of technical complementarity between the two sectors.

These above conflicting hypotheses have major implications for science and technology policy. If there is a unidirectional causality running from public R&D to private R&D, a fall in public R&D could lead not only to a fall in private R&D but can have also a negative impact on economic growth as R&D is an important input into the source of technological progress. In contrast, if there is an opposite uni-directional causality running from private R&D to public R&D, it may imply that reducing private R&D can have an adverse effect on public R&D, which again may have an adverse impact on economic growth. On the other hand, if there is no causality running in any direction, increases in public R&D may not crowd out private R&D and private R&D may not have an impact on public R&D. In contrast, if there is a bi-directional causality between the two, increases in public R&D can stimulate private R&D and private R&D can in turn complement public R&D. On the other hand, if there is a reduction in public R&D investment, it may have a negative effect on the growth of private R&D investment.

3.   METHODOLOGY

As previously stated, cointegration test is carried out by using the Pesaran *et al.* (2001) procedure. The ARDL test is based on the estimation of a dynamic error correction representation for the variables involved and tests whether or not the lagged levels of the variables are statistically significant by estimating unrestricted error correction (UREC) regressions considering each variable in turn as a dependent variable:

$$\Delta LP_t = \alpha_0 + \sum_{i=1}^{p} \beta_{1i} \Delta LP_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta LG_{t-i} + \eta_1 LP_{t-1} + \eta_2 LG_{t-1} + \mu_{1t}, \tag{1}$$

$$\Delta LG_t = \beta_0 + \sum_{i=1}^{p} \nu_{1i} \Delta LP_{t-i} + \sum_{i=1}^{p} \nu_{2i} \Delta LG_{t-i} + \delta_1 LP_{t-1} + \delta_2 LG_{t-1} + \upsilon_{1t}, \tag{2}$$

where LG_t and LP_t are the logs of real private and real public R&D expenditure respectively. The data are for the period 1979-2007 and were taken from the various issues of *Taiwan Statistical Yearbook* and they are in constant prices deflated by the GDP deflator (2001=100). Data on R&D in Taiwan is only available since 1979. In Eq. (1) we test for the joint significance of the lagged levels of the variables using the F-test where the null of no cointegration is defined by $H_0 : \eta_1 = \eta_2 = 0$ against the alternative

that $H_1 : \eta_1 \neq \eta_2 \neq 0$. Similarly, in Eq. (2) $H_0 : \delta_1 = \delta_2 = 0$ against the alternative that $H_1 : \delta_1 \neq \delta_2 \neq 0$. We denote the test that is normalised on LP by $F_{LP}(LP|LG)$ and that is normalised on LG by $F_{LG}(LG|LP)$. The asymptotic distribution of the F-test is non-standard under the null and is derived and tabulated in Pesaran *et al.* (2001) and extended by Narayan (2005) to accommodate small samples. Two sets of critical values are provided: one which is appropriate when all the series are I(0) and the other is for all the series that are I(1), thus covering all the possible classifications of the series into I(0), I(1) or mutually cointegrated (Pesaran *et al.* (2001)). If the computed F-statistic falls above the critical bounds, a conclusive inference can be made regarding cointegration without the need to know the order of integration of the series. In this case, the null of no cointegration is rejected regardless of whether the series are I(0) or I(1). Alternatively, when the test statistic falls below a lower critical value, the null hypothesis is accepted, again regardless of whether the series are I(0) or I(1). In contrast, if the computed F-statistic falls inside the lower and upper bounds, a conclusive inference cannot be made unless we know the order of integration of the series under consideration.

For causality test, we use the modified version of the Granger causality test due to Toda and Yamamoto (1995). The approach proposed by Toda and Yamamoto (1995) is to employ a modified Wald test (MWALD) for restriction on the parameters of the VAR (k) where k is the lag length of the system. The basic idea of this approach is to artificially augment the correct order, k, by the maximal order of integration, say d_{max}. Once this is done, a $(k + d_{max})^{th}$ order of VAR is estimated and the coefficients of the last lagged d_{max} vectors are ignored (see Caporale and Pittis (1999)). Therefore, in order to apply the Toda and Yamamoto (1995) approach, we need to know the true lag length (k) and the maximum order of integration (d_{max}) of the series under consideration. The novelty of the Toda and Yamamoto (1995) procedure is that it does not require pre-testing for the cointegrating properties of the system and thus avoids the potential bias associated with unit roots and cointegration tests (see Clark and Mizra (2006)). The test (MWALD) statistic is valid regardless of whether a series is I(0), I(1) or I(2), non-cointegrated or cointegrated of any arbitrary order 'so long as the order of integration of the process does not exceed the true lag length of the model' (Toda and Yamamoto (1995, p. 225)). To undertake the Toda and Yamamoto (1995) version of the Granger non-causality test, we represent our model in the following equations estimated by the SUR method (see Rambaldi and Doran (1996)):

$$LP_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} LP_{t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{2j} LP_{t-j} + \sum_{i=1}^{k} \gamma_{1i} LG_{t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{2j} LG_{t-j} + \varepsilon_{1t}, \qquad (3)$$

$$LG_t = \beta_0 + \sum_{i=1}^{k} \phi_{1i} LP_{t-i} + \sum_{j=k+1}^{d_{max}} \omega_{1j} LP_{t-j} + \sum_{i=1}^{k} \sigma_{1i} LG_{t-i} + \sum_{j=k+1}^{d_{max}} \sigma_{2j} LG_{t-j} + \varepsilon_{2t}, \qquad (4)$$

where the series are defined above. From (3), LG_t Granger causes LP_t if $v_{1i} \neq 0 \ \forall_i$ Similarly in (4) LP_t Granger causes LG_t implies $\phi_{1i} \neq 0 \ \forall_i$.

4.   EMPIRICAL EVIDENCE

In this section, we present results of cointegration tests, estimates of cointegration regression by using the DOLS and the FMOLS techniques, as well as Granger causality tests and impulse response tests based on VAR analysis. Regarding the ARDL test for cointegration when LP was the dependent variable we find that the estimated F-statistics $F_{LP}(LP|LG)$ was 2.304, whcih is lower than the lower and upper bound of the F-critical value tabulated for 30 observations in Narayan (2005).[1] No matter which lag we used, the null hypothesis of no cointegration cannot be rejected when private R&D (LP) is the dependent variable as in Equation (1). Therefore, the null hypothesis that the level variable does not enter significantly in the equation for LP cannot be rejected. However, when LG is the dependent variable, the F-statistic, $F_{LG}(LG|LP) = 9.636$ was higher than the 1% upper bound of the F-critical value tabulated for 30 observations in Narayan (2005). This shows that there is a long-run relationship between the variables when LP is the forcing variable and that the series are cointegrated.[2]

Since our results support the existence of a cointegration, we estimate the long-run coefficients when LG is the dependent variable. Table 1 shows that private R&D has a positive and a statistically significant impact on public R&D. To test the robustness of our results, the long-run coefficients were additionally estimated using the DOLS and FMOLS methods (see Narayan and Narayan (2005)). As can be seen from Table 1, the robustness of the long-run result obtained by the ARDL method is also verified by the DOLS and FMOL tests. All tests are statistically significant at the 1% level implying that that private R&D had a positive and significant impact on public R&D with almost identical coefficient sizes for all tests. As Table 1 indicates, a 1 per cent increase in private R&D investment induces between 0.50 and 0.64 per cent increase in public R&D.

---

[1] The critical value ranges of F-statistics with one explanatory variable are: 8.170-9.285, 5.395-6.350 and 4.290-5.080 at 1%, 5% and 10% level of significance respectively (see Narayan (2005, p. 1988, Case III). The optimum lag ($p = 3$) was selected by AIC and SBIC and several misspecification tests applied to ensure that the classical regression assumptions were not violated.

[2] Tests for stationarity of the variables was also carried out as the F-statistic of the Pesaran *et al.* (2001) test are not valid in the series are I(2) because the bounds test is based on the assumption that the series are I(0) or I(1). For this purpose, we used several tests (see Madalla and Kim (1998)). After we carried out tests of integration with structural breaks, we found that the public R&D was I(0), while private R&D was I(1).

Table 1.   Estimated Long Run Coefficients, Dependent Variable *LG*

	Coefficient of *LP*	Standard Error	T-ratio[Prob]
ARDL(1,1)	0.484	0.061	5.59[0.000]***
DOLS	0.621	0.096	31.04[0.000]***
FMOLS	0.642	0.028	24.26[0.000]***
OLSQ	0.631	0.121	31.45[0.000]***

Note: *** denotes significant at 1%.

Table 2 shows that the error correction term is statistically significant and has the correct sign indicating that there is a long-run cointegrating relationship between public and private R&D. The speed of adjustment towards equilibrium is moderate with almost a quarter (24%) of the disequilibrium corrected in the first year.

Table 2.   Error Correction Representation for the Selected ARDL Model: ARDL (1, 1) Selected Based on Akaike Info Criterion, Dependent Variable, ΔLG

Regressors	Coefficient	Standard Error	T-Ratio[Prob]
ΔLP_{t-1}	-0.033	0.100	-0.33[0.744]
Constant	1.400	0.407	3.44[0.002]***
ecm(-1)	-0.241	0.106	-2.26[0.033]**

Notes: *** and ** denote significant at 1% and 5% respectively.

R-Squared	0.42	R-Bar-Squared	0.34
S.E. of Regression	0.06	F-stat. F(2,24)	8.16[0.002]
DW-statistic	1.84		

To complement the above results we also carried out Granger causality tests and results of these tests are presented in Table 3. The tests where carried by including a dummy variable that took into account the structural break in 1993.[3] Table 3 shows that there is a bi-directional causality running between private and public R&D; public R&D 'crowds in' rather than 'crowds out' private R&D. Our result of bi-directional causality is consistent with that found by Yoo (2004) for Korea and by Archibald and Pereira (2003) for the USA and in line with other studies that found complementary relationship (see David *et al.* (2000)). In country where private investment is nurtured, it is not surprising to find out that public R&D investment crowds in rather than crowds out

---

[3] I am grateful to the referee of the Journal for suggesting that I carry out causality testing by including a dummy variable that took into account the structural break that took place in 1993.

private R&D investment.

Table 3. Granger Non-Causality Test

	LG does not cause LP			LP does not cause LG		
	lags					
	1	2	3	1	2	3
χ^2	2.47	17.17	19.87	6.27	7.17	34.13
ρ-value	0.12	0.00***	0.00***	0.01***	0.03**	0.00***
Σ of lagged coefficients	0.32	0.71	0.77	0.25	0.25	0.50

Notes: *** and ** denote significant at 1% and 5% respectively. The optimum lag ($k = 1$) was selected by AIC and SBIC but since many misspecification tests were violated using this lag length, we have used $k = 2$. With $k = 2$, no major departures from normal regression assumptions were violated (result available). The test carried out with private R&D I(1) and public R&D I(0). Even when the order of integration of the series was 1 ($d_{max} = 1$), the results were the same.

The above Granger causality tests are within sample causality tests and do not permit an assessment of the relative strength of the Granger-causal effects beyond the sample period. In order to quantify how much feedback exists from one variable to another, we used the recently developed generalized forecast error variance decomposition technique due to Pesaran and Shin (1998), which does not depend on the ordering of the variables. As Table 4 indicates, over a 5-year horizon, public R&D appears to explain 21% of private R&D similarly private R&D explains 24% of forecast error variance of public R&D investment. Over the 10-year horizons, public R&D explains 31% of the forecast error variance of privates R&D while private R&D explains 28% of forecast error variance of public R&D. Thus, the variance decomposition analysis seems to reinforce the complimentary relationship found between public R&D and private R&D by the Granger causality test.

Table 4. Generalized Forecast Error Variance Decompositions

Horizon	Generalized forecast error variance of Private R&D		Generalized forecast error variance of Public R&D	
	Private R&D	Public R&D	Public R&D	Private R&D
1	99.5	4.0	91.5	9.0
5	79.7	21.3	78.3	24.1
10	70.7	30.8	74.8	27.9
15	66.7	35.1	73.5	29.4

Notes: Unlike the orthogonalised case, the row values for the generalized decompositions do not have to sum up to 100. The generalized version gives an ''optimal'' measure of the amount of forecast error variance

decomposition for each series.

5.   CONCLUSION

In this paper attempts have been made to test the cointegration and causal relationship between private and public R&D expenditure in Taiwan for the period 1979-2007. The paper finds a long-run cointegration relationship with a bi-directional Granger causality between private R&D and public R&D investment. Public and private R&D investment complement each other and that public R&D innovation positively contributes to private R&D. This relationship may imply that failure to increase public R&D expenditure may result in lower private R&D investment where it can lead to low technical progress. Thus, the Government of the ROC is justified in planning to bring R&D expenditure to the level achieved by developed countries. Taiwan should continue to invest not only to stimulate private R&D investment but also to enable the country to compete globally in advanced technology. Once again, the experience of South Korea and Taiwan seems to suggest that nurturing the private sector is the way forward to the leap in the next technological ladder that is becoming the backbone of these two countries.

REFERENCES

Archibald, R.B., and A.M. Pereira (2003), "Effects of Public and Private R&D on Private Sector Performance in the United States," *Public Finance Review*, 31, 429-451.

Akyuz, Y., and C. Gore (1996), "The Investment-Profits Nexus in East Asian Industrialization," *World Development*, 24, 461-470.

Akyüz, Y., H. Chang, and R. Kozul-Wright (1998), "New Development on East Asia Development," *Journal of Development Studies*, 34, 4-35.

Caporale, G.M., and N. Pittis (1999), "Efficient Estimation of Cointegrating Vectors and Testing for Causality in Vector Autoregressions," *Journal of Economic Surveys*, 13, 3-35.

Chen, S. (1999), "Towards a Knowledge-based Economy: Taiwan's Experience in Developing Science and Technology-based Industries," *Industry of Free China*, March, 93-110.

Chen, S., M. Liu, M.J. Chen, and C. Hsiao (2004), "The Strategy for Raising R&D Intensity of Taiwan," Paper presented at the International Conference on 2004 Industrial Technology: Growth Engines of Innovation-driven Economy, Taipei, R.O.C.

David, P.A., B.H. Hall, and A.A. Toole (2000), "Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence," *Research

Policy, 29, 497- 529.

Enders, W. (2004), *Applied Econometric Time Series*, 2nd Ed., New York, John Wiley & Sons, Inc.

Fang, S.-C., J.L. Lin, L.Y.C. Hsiao, C.-M. Huang, and S.-R. Fang, (2002), "The Relationship of Foreign R&D Units in Taiwan and the Taiwanese Knowledge Flow System," *Technovation*, 22, 371-383.

Kónya, L. (2004), "Export-led Growth, Growth-driven Export, Both or None? Granger Causality Analysis on OECD Countries," *Applied Econometrics and International Development*, 4, 73-97.

Leyden, D.P., and A.I Link (1991), "Why are Government R&D and Private R&D Complements?" *Applied Economics*, 23, 1673-1681.

Lin, M.-W. (2001), "Technology policy in Hard Times, or How Taiwan is Coping with the Current Economic Downturn" (Memo).

Lütkepohl, H. (1993), *Introduction to Multiple Time Series*, 2nd Ed., Berlin: Spring-Verlag.

Madalla, G.S., and I.M. Kim (1998), *Unit Roots, Cointegration, and Structural Change*, Cambridge, Cambridge University Press.

Mahmood, I.P., and J. Singh (2003), "Technological Dynamism in Asia," *Research Policy*, 32, 1031-1054.

Mathews, J.A. (2002), "The Origins and Dynamics of Taiwan's R&D Consortia," *Research Policy*, 32, 633-651.

Nagano, M. (2006), "R&D Investment and the Government's R&D policies of Electronics Industry in Korea and Taiwan," *Journal of Asian Economics*, 17, 653-666.

Narayan, P.K. (2005), "The Saving and Investment Nexus for China: Evidence from Cointegration Tests," *Applied Economics*, 37, 1979-1990.

Narayan, P., and S. Narayan (2005), "Estimating Income and Price Elasticities of Imports for Fiji in a Cointegration Framework" *Economic Modelling*, 22, 423-438.

Pesaran, M.H., and Y. Shin (1998), "Generalised Impulse Response Analysis in Linear Multivariate Models," *Economics Letters*, 58, 17-29.

Pesaran, M.H., Y. Shin, and A. Smith (2001), "Bounds Testing Approach to the Analysis of Level Relationships," *Journal of Applied Econometrics*, 16, 289-326.

Phillips, P., and B. Hansen (1990), "Statistical Inference in Instrumental Variables with I(1) Processes," *Review of Economic Studies*, 57, 99-124.

Rambaldi, A.N., and T.E. Doran (1996), "Testing for Granger Non-Causality in Cointegrated System Made Easy," Working Papers in Econometrics and Applied Statistics, 88, Department of Econometrics, University of New England.

Rodrik, D. (1995), "Trade Strategy, Investment, and Exports: Another Look at East Asia," BER Working Paper, 5339.

Shyu, J.Z., and Y.-C. Chiu (2002), "Innovation Policy for Developing Taiwan's Competitive Advantage," *R&D Management*, 32, 369-374.

Stock, J., and M.W. Watson (1993), "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems," *Econometrica*, 61, 783-820.

Toda, H.Y., and T. Yamamoto (1995), "Statistical Inference in Vector Autoregressions with Possibly Integrated Process," *Journal of Econometrics*, 66, 225-250.

UNCTAD (2003), *Investment and Technology Policies for Competitiveness: Review of Successful Country Experiences*, Geneva.

Wolde-Rufael, Y. (2005), "Energy Demand and Economic Growth: The African Experience," *Journal of Policy Modeling*, 27, 891-903.

Yang, C.-H. (2006), "Is Innovation the Story of Taiwan's Economic Growtt?" *Journal of Asian Economics*, 17, 867-878.

Yoo, S.-H. (2004), "Public R&D Expenditure and Private R&D Expenditure: A Causality Analysis," *Applied Economics Letters*, 11, 711-714.

Mailing Address: 135 Carnwath Road, London SW6 3HR, England. Tel: 44-20-7974-1997.

E-mail: ywolde@btinternet.com