Long-Run Behavior of R&D Investment and Economic Growth : A Macro-Econometric Model

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ABSTRACT

This study investigates how and through which channels R&D activities influences the national economy, using a macro-econometric model. The macro-econometric model in this study includes 24 behavioral equations and 25 identities and was estimated using the annual data. From a simulation analysis, it is shown that the R&D investment has a permanent effect on real variables; lowering prices, wages and interest rates, and increasing potential and real GDP in the long run. It is noted that the national account was recalculated to avoid double-counting in estimation of R&D stocks.

Keywords: R&D investment, R&D stocks, endogenous growth theory, macro-econometric model.

JEL Classification: 023, 030, 040 & 047

1. INTRODUCTION

Recently, technological innovation is recognized to play an important role in economic growth. It tends to be increasingly complex as more players interact one another in the process of innovation. In 1990s, so-called new economy, which is arguable [1], might be driven by technological innovation, i.e., IT revolution. Today's innovation is by and large influenced by organized R&D activities. Although it is not well investigated if there is a systematic relationship between R&D activity as an input and technological innovation as an output, they certainly move in the same direction.[1] Thus, R&D activity could be recognized as one of important factors determining innovation.

The Korean economy experienced serious reforms in the private and public sector, right after the foreign exchange crisis in the end of 1977. The R&D sector was of course no exception. But the impact of such economic turbulence on the R&D activities was not well investigated, and in turn economic consequence of major cutback in R&D activities was neither. Shin [2] investigated the economic effect of R&D investment. However, it was limited only to estimating the contribution of R&D investment to economic growth though a Solow type of the neoclassical production function at the aggregate level. It might be more interesting, therefore, to assess the mechanism and channels that R&D activities influence the national economy, relating it to other macro-economic variables within a model.

Thus, the primary purpose of this study is to find out some empirical evidences about how and through which channels R&D activities are related to and influence the national economy, establishing a macro-econometric model. In so doing, it was necessary to separate the R&D sector from the demand side of the economy. We assume that technological progress is determined by R&D activities. Then due to technological progress, the national economy exhibits increasing returns, as in the endogenous growth theory.

This study is organized as follows. In the chapter 2, we discuss the potential GDP. Estimation of the potential GDP is necessary in order to include the supply side into the model. To do this, we had to recalculate the national account and to estimate the natural rate of unemployment. Then, we establish the macro-econometric model including the R&D sector and have a discussion about the adjustment mechanism. In chapter 4, we provide the estimation results of the model and the simulation results for alternative policy measures. Finally, we provide concluding remarks in chapter 5. The estimation and simulation results are reported in the appendices. A comparison of the policy effects among the alternative measures is shown in statistics and figures. The list of variables can be also read from the appendix.

2. POTENTIAL GDP

[1] Today's technological leaders such as the United States, Japan and Germany, etc., exhibit the high ratio of R&D expenditures to GDP.

2.1 The Production Function

Modeling the supply side, the potential GDP has to be firstly obtained. The potential GDP represents the maximum output at the natural rate of unemployment, which does not accelerate the rate of inflation. There are various ways to estimate the potential GDP. In this study, we employed a neoclassical production function, borrowing an idea from the endogenous growth theory.

A Cobb-Douglas production function is assumed with increasing returns to scale. We also assume that the increasing returns are caused by technological progress. Therefore, constant returns to scale are assumed in production inputs of labor and capital only, and technological progress is assumed to be a function of R&D stocks.

Consider that a production function is given by $Q = A(g)f(K, L)$, technological progress, $A(g)$, is determined exogenously in the neoclassical approach, so that it is simply specified as a function of the time period; with an assumption of a constant returns to scale. However, the endogenous growth theory envisions increasing returns to scale in the production function. Such increasing returns are mainly determined by technological progress. Technological progress can be built in by specifying the model as $A = f(K)$, $A = f(L)$ or $A = f(K, L)$. It is pointed out that:[2]

"The real problem is 'A". The EGT theory hasn't provided, so far, neither a conceptual foundation nor a clear answer on how 'A' can be measured. In too many contributions to Endogenous Growth Theory (EGT) though not in all central reference is made to `a stock of knowledge', a `stock of ideas', etc., this variable featuring centre-stage in the analysis. Yet it is immediately apparent that this is far from being a crystal clear concept. Is knowledge a homogeneous quantity of which there is simply more or less? Clearly not. One may wonder to what extent knowledge is truly non-rivalrous, as opposed to being specific to sets of individuals and, to the extent that knowledge is held in common, whether one ought not to think of the `total' stock as being the union rather than the sum of `individual stocks'. (Olsson, 2001, pp. 10-11) Even if `knowledge' either is or can be rendered homogeneous and that is a very big `if', the question arises whether there exists any cardinal measure of the single stock of knowledge. It is common in the EGT literature to treat the `stock of knowledge' as if it were a single magnitude with a cardinal measure, without any justification being given for this assumption.

In his famous `learning-by-doing' paper (1962), Arrow painted a `picture of technical change as a vast and prolonged process of learning about the environment in which we operate'. (p.155) He went straight on, however, to refer to a variable `so difficult to measure as the quantity of knowledge'. (ibidem) Sensibly, therefore, Arrow did not make any `amount of knowledge' a central variable in his analysis but used, rather, cumulative gross investment- a measurable variable taken to be positively related to the acquisition of knowledge. Not everyone has followed Arrow's excellent (and very early) lead.

Romer's (1990) paper makes little advance with respect to the issues at hand. Romer refers to Arrow

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[2] The author is greatly indebted to an anonymous referee for this comments.

(1962) as assuming that `an increase in K (the capital stock) necessarily leads to an equiproportionate increase in knowledge' [does Arrow actually say this?] and by (p.S77) we are reading of non-rival knowledge and of A as `the benefits of research and development'. Are `knowledge' and `the benefits of R & D' synonymous expressions? Either way, are there cardinal measures of these magnitudes? In his §III, Romer explains that, `The four basic inputs in this model are capital, labor, human capital, and an index of the level of technology'. (pp.S78-S79)
Just how can an `index of the level of technology' be an input to a productive process? It is noteworthy that Romer makes fairly clear remarks on how to measure the first two `inputs', some vaguer remarks on measuring the third `input' and says nothing whatever on how to measure the fourth. According to Romer, the `existing stock of knowledge' is an input in the research sector (p.S79); is the `stock of knowledge' the same thing as the `index of the level of technology'? Can a `stock' be an `index'? If they are not the same thing, how are they related? In any case, the product of the research sector is designs for new producer durables (p.S79) or, by the next page, `new designs or knowledge' (p.S80). At this stage in Romer's analysis 'A' becomes an integer; but he is not really claiming to have produced a cardinal measure of the level of technology/knowledge/designs. The integer nature of A is a mere artefact.

A ray of hope has been provided recently by Aghion and Howitt, who offer a 14 page appendix *`On Some Problems in Measuring Knowledge-Based Growth.' (1998, pp.435-448;)* They note immediately that `we do not have any generally accepted empirical measures of such key theoretical concepts as the stock of technological knowledge, human capital ... the rate of obsolescence of old knowledge, and so forth.' (p.435) And they make it perfectly clear that the problem is not a purely empirical or data problem: `It would be more accurate to say that formal theory is ahead of conceptual clarity. Only when theory produces clear conceptual categories will it be possible to measure them accurately'. (ibidem) Aghion and Howitt do not pretend to have resolved all the relevant issues, far from it. But they do identify the problem at hand and begin to think it through. (It is to be hoped that their attempt attracts more attention than did Arrow's clear (1962) warning.) They conclude: `If the critical component of our discussion in this appendix has been larger than the constructive component, this is mainly attributable to the fact that what is at issue is not something likely to be fixed by minor tinkering with national income accounting practices ... a better conceptual foundation is needed before we know just what magnitudes to look at and how.' (p.447)"

It could be argued that technological progress is also determined by R&D activities. Then technological progress can be specified as $A = f(R)$, where R denotes R&D stocks.[3] We may write a Cobb-Douglas production function as follows;

(1) $$\log GDP_t = A(R_t) f(K_t, L_t)$$
$$= \beta_0 + \beta_1 \log(KSTRD_t \times MORI_t) + (1-\beta_1)\log(YDAY_t \times EMPD_t) + \beta_2 RDSTK_t + \varepsilon_t$$

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[3] See in detail Romer (1994). [1]

where GDP_t denotes gross domestic product; $KSTRD_t$ capital stocks of non R&D sector; $MORI_t$ operation rate of the manufacturing; $EMPD_t$ number of the employed in non-R&D sector; $YDAY_t$ annual workdays; $RDSTK_t$ R&D stocks; and $\varepsilon_t : N(0,\sigma^2)$ the statistical error term.

2.2 National Account Data and R&S Stocks

To estimate Eq.(1), it is necessary to obtain the capital stock and R&D stock. The reported data of the national account by the Bank of Korea consist of

$$(2) \qquad GDP_t = (CPV_t + CPB_t) + (KIH_t + KIQ_t) + (EX_t - IM_t) + SDI_t$$

where CPV_t denotes private consumption expenditures; CPB_t government expenditures; KIH_t housing and construction investment; KIQ_t plant and equipment investment; EX_t exports; IM_t imports and SDI_t statistical adjustment.

However, the R&D expenditures consist of fixed capital formation (housing and construction plus equipments) and the consumption expenditures, which are already included data on the national account. To avoid double-counting, we break down R&D expenditures and national accounts into lower level items, and recalculate the data on the national account, by subtracting the same items of R&D expenditures from the items of consumption and investment on the national accounts. After correcting the data, Eq.(2) is rewritten as follows;

$$(3) \qquad GDP_t = CRD_t + KIRD_t + RDI_t + (EX_t - IM_t) + SDI_t$$

where CRD_t denotes both private and government consumption expenditures, $KIRD_t$ both housing & construction and plant & equipment investments of the non-R&D sector; RDI_t R&D investment; and others are the same as before.

<Table 1> Basic Assumptions for R&D Stocks

	Private Sector	Public Sector
R&D lags	2 years	3 years
Rate of knowledge obsolescence	0.125	0.125

Rearranging the national account in such a way, now, we can estimate capital stocks and R&D stocks. The capital stocks were obtained from statistics of the national wealth and gross investment, using the polynomial-bench-mark methods.[4] Using the polynomial-bench-mark method, the average depreciation rates were obtained for the period of 1968-78 and 1978-88. On the other hand, under certain assumptions, the R&D stocks were estimated using the perpetual inventory method. To get the R&D stocks, the information about the lag structure and the rate of knowledge obsolescence--equivalent to the depreciation rate of the capital stocks--and R&D deflator. We assume that the time lags of R&D investment are 2 and 3 years for the private and public sectors, respectively. We also assume that the rate of knowledge obsolescence is 0.125.[5] For the convenience, the GDP deflator is employed in place of the R&D deflator.

The production was estimated by the Least Sqaures (LS) method. The estimation results of the aggregate production function are shown below;

(4)
$$\log GDP_t = \underset{(-24.98)}{-5.852} + \underset{(4.829)}{0.304} \log(KSTRD_t \times MORI_t)$$
$$+(1 - 0.3043)\log(YDAY_t \times EMPD_t) + \underset{(5.678)}{0.2097} \log RDSTK_t$$

$$R^2 = 0.997, \quad D.W. = 0.409, \quad Sample: 1975 : 1994$$

where $MORI_t$ denotes the index for manufacturing operation rate; $YDAY_t$ annual workdays per worker in the manufacturing sector, $EMPD_t$ the number of the employed; and numbers in the parentheses are t-values. From Eq.(4), all the estimates are statistically significant and R^2 is high, although $D.W.$ statistics is not good.

2.3 Natural Rate of Unemployment and Potential GDP

The natural rate of unemployment is firstly estimated, using the price equation. According to Gordon (1982), the price equation may be given by

(5)
$$\dot{P}_t = \beta_0 + \beta_1 \dot{P}_{t-1} + \beta_2 U_t + \beta_3 \dot{U}_t + \beta_4 \dot{X}_t + \varepsilon_t$$

where $\dot{P}_t$ denotes changes in the price, U_t rate of unemployment, $\dot{U}_t$ changes in the rate of unemployment, and $\dot{X}_t$ supply/demand side factors influencing inflation, and $\varepsilon_t \sim N(0,\sigma^2)$. Assuming Eq.(1), then, by definition, the natural rate of unemployment, $\hat{U}_t$, can be obtained as follows;

(6)
$$U_t^* = \beta_0 / \beta_2$$

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[4] The national stocks are measured and reported every 10 years by the Bank of Korea.

[5] Estimation of the lag structure of R&D activities is no easy matter, since the lag structures of different areas of science and technology vary widely. Most studies thus assumed simply a constant value of the lag. For example, P. Pattel & L. Soete (1988) assumed that the rate of knowledge obsolescence was 0.15.

For the convenience, we assumed that the rate of inflation at time t is equal to the weighted average of the rates of inflation in the past. Then, we can write

$$(7) \qquad \dot{P}^e_t = \dot{P}_t - \left[\frac{\sum_{i=1}^{5} \hat{\beta}_i \dot{P}_{t-i}}{\sum_{i=1}^{5} \hat{\beta}_i} \right]$$

Replacing Eq.(7) into Eq.(5) and estimating the equation, we have

$$(8) \qquad \dot{P}^e_t = \underset{(2.663)}{10.803} - \underset{(-3.415)}{4.242U_t} - \underset{(-0.667)}{0.053\dot{U}_t} + \underset{(3.045)}{0.300\dot{P}^M_t}$$

where $\dot{P}^M_t$ denotes import prices and the numbers of parentheses are t-values. Thus, the natural rate of unemployment will be

$$(9) \qquad U_t^* = 10.803 / 4.242 = 2.547$$

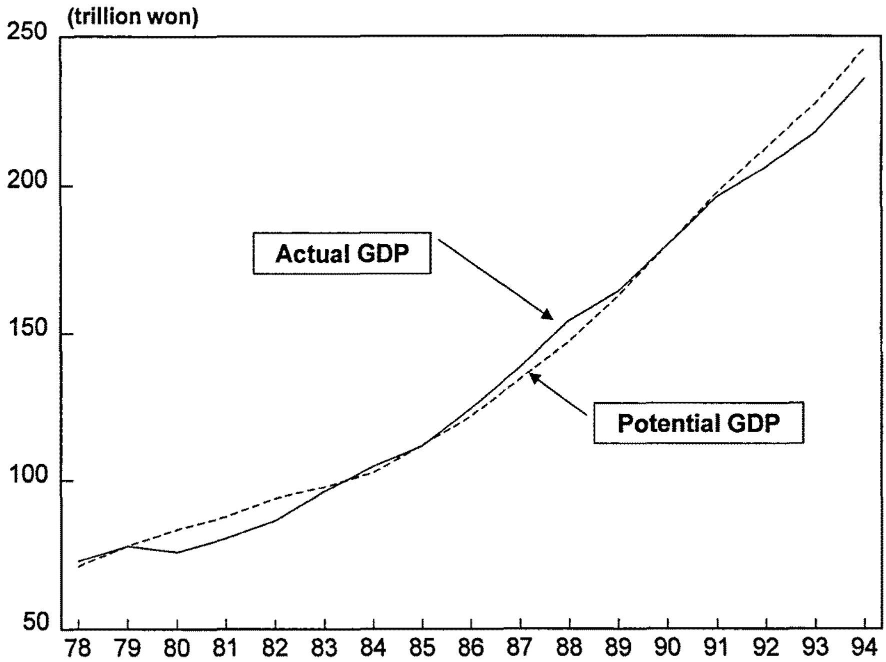
Since the natural rate of unemployment is determined by Eq.(9), the number of the employed at the natural rate of unemployment, $EMPD_t^N$ can be calculated by deducting the number of the unemployed under the natural rate of unemployment from economically active population minus R&D manpower.[6]

$$(10) \qquad EMPD_t^N = (LF - RDMN) - (U_t^* \times LF_t / 100)$$

where LF_t denotes economically active population; $RDMN_t$ the number of researchers

<Fig. 1> Actual GDP and Potential GDP

[6] . In this study, the economically active population is endogenously determined by the rate of participation in economic activities. More discussion will be made later.



Obtaining the potential GDP by replacing (Eq. 10) into (Eq.4), a comparison between the actual GDP and potential GDP can be shown in <Fig. 1>. It is noted that the potential GDP is greater than the actual GDP in early 1980s and 1990s, showing economic slowdown. On the other hand, the actual GDP is greater than the potential GDP in the late 1980s, showing an economic boom--by and large due to the Seoul Olympiad in 1988. This implies that the GDP gap--difference between the potential and real GDP--plays an important role of economic adjustment.

3. THE MODEL AND AJUSTMENT MECHANISM

3.1. The Model Structure

The model of this study is a small-scale macro-econometric model, including 25 identities and 24 behavioral equations. The model is employed in order to analyze the effect of R&D investment on the national economy, rather than to focus economic forecast. Therefore, it is essential to establish the R&D sector in the model. The model is divided into the several sectors, such as real sector, aggregate production function, monetary sector, foreign trade sector, and prices which link all different sectors of the economy. In the production function, R&D stocks were introduced as a determinant of technological progress as discussed above.

The model is structured as follows. The supply side of the model determines capital stocks, R&D stocks, and potential GDP. Labor and wages on the other hand are determined in the labor market. The demand side of the product market will determine the sizes of consumption expenditures, investment expenditures in construction, plant/equipment and R&D, exports, imports, inventories and real GDP. In addition, consumer prices, wholesale prices and GDP deflators are endogenously determined in the demand side. In the foreign trade, exports and imports based on the balance of payments (BOP) and their prices are determined, and consequently, so are the trade and current balances. Then, using the bridge equations, the export and import are transformed into the national accounts. The monetary sector determines money demand/supply (M2) and interest rates. Finally, the public finance is included.

3.2. Adjustment Mechanism of the Model

In this model, the potential GDP is determined endogenously and the interaction of real GDP and potential GDP guide the equilibrium of the national economy. In this line, it is built into the model how R&D activities influence the national economy.[7]

The adjustment mechanism can be described as follows. If any shock is given to the model, the subsequent dynamic interaction between macro-economic variables can be shown the clock-wise direction in <Fig. 2>. First, in the north of <Fig. 2>, the potential GDP is determined by labor supply, capital stocks and R&D stocks. Then, the gap between the potential GDP and real GDP will determine the excess demand at the aggregate level. The aggregate excess demand will influence in turn the rate of participation in economic activities and wages. Wages will again influence prices of the real sector. Suppose that the excess demand increases, i.e., the GDP gap narrows, then wages and income of workers will be increased. As income rises, the individual will prefer leisure to work hours. That is, the opportunity cost of leisure is increased. Consequently, the rate of participation in economic activities will drop and labor services will be more expensive. Changes in prices will have direct and indirect effects on R&D and non-R&D sectors of the demand side; and on foreign trade, monetary and public finance sectors. The price will also affect nominal GDP, tax revenues and government spendings on the other hand. It consequently influences money demand/supply. In

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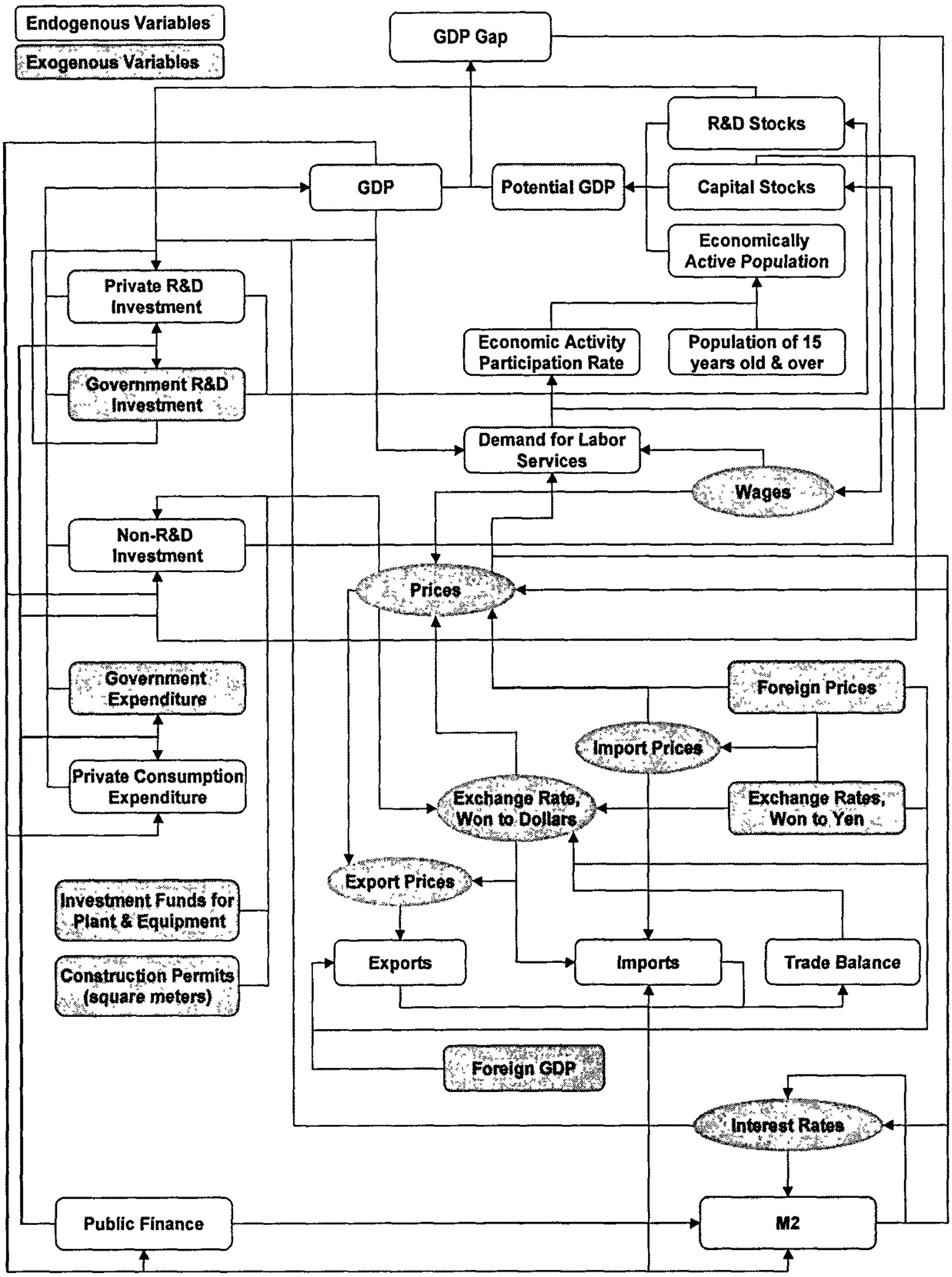
[7] See, for the modelling the supply side into the macro-econometric model, W.K. Park, et. al. (1989) and Giorno, et al. (1995).

<Fig. 2> Flow Chart



such a process, the money market will convey the effects of the real sectors to interest rates, which again passes those effects over to the demand side. As a result, the initial shock will influence the national economy directly and indirectly through the price mechanism. After such an adjustment, the real GDP and potential GDP will change the GDP gap and economic adjustment will continue over.

In the fundamentals of this model, the R&D activities are recognized as a supply shock and have a long-run effect on the national economy. A change in R&D investment will have a demand-side shock in the short run. In time, however, the change in R&D investment will change the R&D stock and therefore influence technological progress as specified in the production function, in the long run, which leads to a change in the potential GDP and therefore the GDP gap. Such a continuous interaction between potential and real GDP will continue until the economy restore a new equilibrium.

Theoretically, real GDP could not surpass the given potential GDP. It would be possible in the short run to raise real GDP near the level of given potential GDP, but economic growth in the long run will be determined by the course of the potential GDP, which is by and large influenced by technological progress. Along this line, R&D activities play an important role in the national economy.

<Table 2> Root Mean Squared Errors (RMSE)

Variables	RMSE (%)	Variables	RMSE (%)
Demand side & prices	2.086	Foreign trade	2.310
GDP	0.735	*EXCB*: commodity exports	2.734
CPVRD: private consumption of non-R&D	0.504	*IMCB*: commodity imports	0.979
Sector	1.383	*EXSNB*: non-factor income from abroad	5.160
KIHRD: construction investment of non-R&D		*IMSNB*: non-factor income to abroad	3.523
sector	3.538	*PX*: export price index	1.342
KIQRD: plant/equipment investment of non-		*PM* import price index	1.450
R&D sector	4.865	*ER*: exchange rates	0.981
RDIPV: private R&D investment	2.102		
PGDP: GDP deflator	1.498	Monetary sector	2.816
CPI: consumer price index	2.061	*RM2*: real M2	1.305
WPI: producer's price index		*RCB*: yields of corporate bonds	4.327
	0.483		
Supply side	0.483	Public finance	3.189
PTGDP: potential GDP		*TXR*: tax revenues	3.714
	1.596	*CGE*: expenditures of central government	2.663
Wages & employment	0.558		
LFPR: participation rate in economic activities	0.704	TOTAL	2.133
EMPD: number of the employed in non-R&D			
sector	1.859		
RDMN: number of researchers	0.854		
RWG: monthly real wage of workers in mining			
and manufacturing sector.	4.003		
RDWG: annual R&D personnel expenses per			
researcher			

4. MODEL ESTIMATION AND SIMULATION FOR ALTERNATIVE POLICY MEASURES

The specification of the model can be referred in the Appendix, where estimation results are reported, and the statistical error terms of all behavioral equations are assumed to be $N(0,\sigma^2)$. All equations are estimated by LS method. After each equation is estimated separately, the entire model is solved simultaneously and the goodness of fit is tested.[8] We construct the model in such a way that economic growth is determined endogenously by self-adjusting mechanism. Thus, it has to be confirmed that estimation results assure the economic theory by simulating the model every time after each estimation. On the other hand, we employed the dummy variables to increase the goodness of fit of the model. The statistical data were obtained from the Bank of Korea and National Statistics Office, etc.

The estimation results are reported in the appendix A. The RMSE (root mean squared errors) are shown in <Table 2>. It can be seen that the RMSEs are less than 5% in most equations.

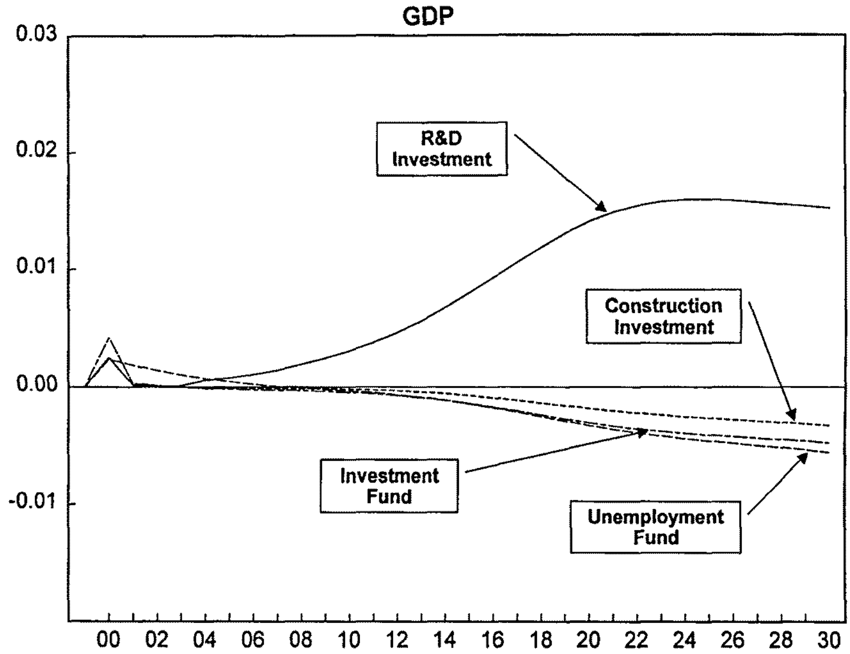
Using the estimated model, a simulation analysis was carried out and a comparison of policy effects of alternative policy instruments. The simulation was carried out over the 30 years period, under the assumption that other things are not changed including the exogenous variables. To do this, first, we solve the model simultaneously without any shock and get the solution, $\hat{X}_t$. Second, we do it again with a shock and get the solution, $\breve{X}_t$, Then, we calculated $(\breve{X}_t - \hat{X}_t)/\hat{X}_t$, which denotes cumulative effects of the shock. But for the variables represented by percentage, such as LFPR, RCB, UR, we get $(\breve{X}_t - \hat{X}_t)$, which are represented by the percentage point. The shock is given by one trillion won increase in R&D investment, construction investment, the investment funds for plants & equipments and unemployment (relief) fund through the deficit financing.

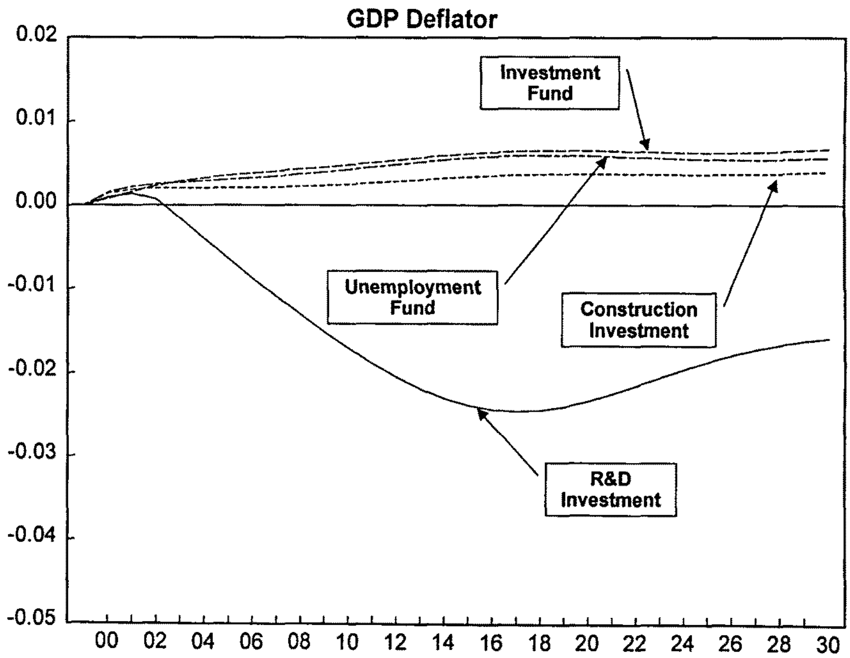
First, if the aggregate demand through a policy measure of the unemployment fund, investment fund for plants and equipments, construction investment, or R&D investment is increased by deficit financing, there will be a demand shock in the beginning year. By such a demand shock, real GDP will be increased, and an increase in real income will stimulate investment in R&D, construction and plants and equipments on the one hand. It also increases the consumption on the other hand. This will again increase real GDP. Thus, there will be direct and indirect effects of a demand shock on real income. Then, the GDP gap will narrow, given the potential GDP. As the change in the GDP gap will influence wages and prices, the adjustment starts. However, such a demand shock will increase the price level and thereby offset the effect of initial increase in real GDP in the following years. Therefore, in the long run, the stabilization policy of demand management will eventually have only short-run effect, but increase the price level permanently.

<Fig. 3> Simulation Results by Alternative Policy Measures: cumulative effects of one

[8] In some cases, the macro-econometric model includes a structural nature, using VAR (vector auto-regressive) model, such that "the demand shock does not influence real economic growth in the long run." For example, see W.K. Park (1989).

trillion won increase by deficit financing





However, R&D investment unlike other measures will increase in time the R&D stocks. If R&D

stocks are increased, this will stimulate technological progress through the production function. Thus, the potential GDP rises. The increase in the potential GDP will widen the GDP gap, which will lower wages, prices and interest rates. As a consequence, investment and consumption and therefore real income will be increased.

Such policy effects of alternative measures can be shown in <Fig. 3> and <Table 3>. Simulating the model over the time period of 30 years, one trillion won increase in R&D investment will have a cumulative effect of 1.54% on real GDP, but the effects of other measures are nearly zero in the long run.

<Table 3> Cumulative Effect of Alternative Policy Measures; when a 1 trillion won is invested by deficit financing

After	*GDP (%)*				*Unemployment Rate (% point)*			
	R&D investment	Construction investment	Investment fund	Unemployment fund	R&D investment	Construction investment	Investment fund	Unemployment fund
One year	0.25	0.42	0.23	0.42	-0.052	-0.044	-0.025	-0.048
5 years	0.06	-0.01	0.07	-0.01	0.029	0.004	-0.004	0.005
10 years	0.24	-0.02	-0.02	-0.04	-0.037	0.003	0.006	0.008
15 years	0.67	-0.06	-0.11	-0.11	-0.085	0.005	0.012	0.013
20 years	1.30	-0.16	-0.29	-0.27	-0.130	0.014	0.026	0.025
25 years	1.59	-0.25	-0.44	-0.40	-0.136	0.021	0.037	0.033
30 years	1.54	-0.31	-0.54	-0.46	-0.104	0.022	0.037	0.032

5. CONCLUDING REMARKS

An investigation of the relationship of R&D activities to the national economy was attempted through a small-scale macro-econometric model. In establishing the model, we separated the R&D sector from the demand-side and included the supply side. The model was structured so that the interaction between real and potential GDP guides the economy to an equilibrium. In this line, technological progress was seen as a function of R&D activities in view of the endogenous growth theory.

Based on our model. It was shown that R&D activities have a significant effect on the national economy particularly in the long run; lowering prices and increasing real income. However, the conventional policy instruments such as the increase in government spendings for construction, promotion of plant/equipment investment and unemployment fund have only a short-run effect on real income; instead, having a permanent effect on the prices. It could be said, as a consequence, that R&D investment will strengthen future economic potentials and have positive effects on employment and income in the long run. On the other hand, it is shown that real income cannot surpass the potential GDP by demand-management policies in the long run. Such policies have only a short-run effect on real income and employment, which is offset by permanently increasing prices. Such findings consent with economic theories.

It is also pointed out that recalculation of the national accounts was unavoidable to correct the double-counting problem. The critical assumption in this study is that technological progress is determined by the R&D stocks. A set of assumptions was required in estimating R&D stocks; about the lag structure and rate of knowledge obsolescence. Since such assumptions are different in different studies, further investigation would be necessary. However, this remains for future studies. The other limitation of this study is that we have a small sample, because the R&D data is collected only in the annual base and shows a short history in the Korean economy.

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APPENDIX A: ESTIMATION RESULTS

⊙The numbers in the parentheses are *t*-values.

1. Demand Side

(1-1) Gross Domestic Product (NA; billion won at constant prices)

$$GDP_t = CRD_t + KIRD_t + RDI_t + (EX_t - IM_t) + SDI_t$$

(1-2) Gross Consumption Expenditure (NA; billion won at constant prices)

$$CRD_t = CPVRD_t + CPBRD_t$$

(1-2-1) Private Consumption Expenditure (NA; billion won at constant prices)

$$CPVRD_t = \underset{(16.58)}{3447.403} + \underset{(25.94)}{0.3038}(GDP_t - TXR_t \times 100 / PGDP_t) + \underset{(3.247)}{0.0549}(M2_t \times 100 / PGDP_t) + \underset{(22.40)}{0.4653}CPVRD_{t-1}$$

$$-\underset{(-14.11)}{2268.241}DD8788 + \underset{(6.525)}{1235.590}D90 - \underset{(-7.244)}{814.7042}(D77 + D80 + D86) + \underset{(5.493)}{511.8613}(D76 + D79 + D83 + D87 + D91)$$

$R^2 = 0.999,\quad Adj\,R^2 = 0.999,\quad D.W. = 2.401,\quad Sample: 1971:1994$

(1-3) Gross Fixed Capital Formation (NA; billion won at constant prices)

$$KIRD_t = KIHRD_t + KIQRD_t + KINV_t$$

(1-3-1) Construction Investment (NA; billion won at constant prices)

$$KIHRD_t = -\underset{(-15.55)}{3220.693} + \underset{(22.33)}{1.7151}BCP_t + \underset{(29.68)}{0.1416}GDP_t - \underset{(-14.22)}{5207.170}D89 + \underset{(6.616)}{1969.330}DD9192 + \underset{(2.902)}{728.8537}DD7980$$

$$-\underset{(-13.60)}{2818.204}(DD8688 + D90)$$

$R^2 = 0.999,\quad Adj\,R^2 = 0.999,\quad D.W. = 1.712,\quad Sample: 1971:1994$

(1-3-2) Plant/Equipment Investment (NA; billion won at constant prices)

$$KIQRD_t = -\underset{(-0.176)}{126.4973} - \underset{(-9.157)}{277.6063}(RCB_t - INFR_t) + \underset{(2.014)}{0.5697}(LDBC_t \times 100 / PGDP_t) + \underset{(0.796)}{0.0247}GDP_t + \underset{(9.320)}{0.7358}KIQRD_{t-1}$$

$$-\underset{(-11.07)}{4497.963}D93 - \underset{(-5.956)}{2668.075}(D75 + D92) - \underset{(-5.207)}{1119.263}(D80 + D85 + D88) + \underset{(4.921)}{1258.770}(D79 + D94)$$

$R^2 = 0.999,\quad Adj\,R = 0.999,\quad D.W. = 2.228,\quad Sample: 1978:1994$

(1-4) R&D Investment (NA; billion won at constant prices)

$$RDI_t = RDIPV_t + RDIPB_t$$

(1-4-1) Private R&D Investment (NA; billion won at constant prices)

$$RDIPV_t = -\underset{(-26.20)}{1206.346} - \underset{(-4.290)}{9.8294}(RCB_t - INFR_t) + \underset{(17.06)}{0.0166}GDP_t + \underset{(2.655)}{0.5872}RDIPB_t + \underset{(10.55)}{0.0954}RDSTK_{t-1}$$

$$-\underset{(-11.21)}{356.3448}D91 - \underset{(-11.99)}{207.4089}(DD7982 + D90 + D92) + \underset{(5.428)}{135.5103}DD8586 + \underset{(8.748)}{390.8779}D94 - \underset{(-4.840)}{121.1507}(D78 + D83)$$

$R^2 = 0.999, \quad Adj\,R^2 = 0.999, \quad D.W. = 2.613, \quad Sample: 1975:1994$

(1-5) Exports of Goods and Services (NA; billion won at constant prices)

$EX_t = EXC_t + EXSN_t$

(1-5-1) Commodity Exports (NA; billion won at constant prices)

$EXC_t = 0.70797 \times EXCB_t$

(1-5-2) Non-Factor Income from Abroad (NA; billion won at constant prices)

$EXSN_t = 0.70797 \times EXSNB_t$

(1-6) Imports of Goods and Services (NA; billion won at constant prices)

$IM_t = IMC_t + IMSN_t$

(1-6-1) Commodity Imports (NA; billion won at constant prices)

$IMC_t = 0.70797 \times IMCB_t$

(1-6-2) Non-Factor Income to Abroad (NA; billion won at constant prices)

$IMSN_t = 0.70797 \times IMSNB_t$

2. Prices

(2-1) Rate of Inflation (%)

$INFR_t = [(PGDP_t / PGDP_{t-1}) - 1] \times 100$

(2-2) GDP Deflator (1990 = 100)

$$\Delta \log PGDP_t = \underset{(-1.574)}{-0.0122} + \underset{(0.344)}{0.0240}\Delta \log M2_t + \underset{(7.988)}{0.4270}\Delta \log WGE_t + \underset{(15.74)}{0.3447}\Delta \log(PM_t \times ER_t) + \underset{(2.076)}{0.1052}\Delta \log PGDP_{t-1}$$

$$+\underset{(6.709)}{0.0490}(DD7576 + D78) - \underset{(-3.712)}{0.0263}(D80 + D89) + \underset{(3.439)}{0.0242}(D86 + D91)$$

$R^2 = 0.991, \quad Adj\,R^2 = 0.987, \quad D.W. = 2.700, \quad Sample: 1974:1994$

(2-3) Consumer Price Index (1990 = 100)

$$\Delta \log CPI_t = \underset{(-2.852)}{-0.0141} + \underset{(19.79)}{0.8388}\Delta \log PGDP_t + \underset{(4.187)}{0.1721}\Delta \log CPI_{t-1} + \underset{(4.204)}{0.0520}D80 - \underset{(-5.780)}{0.0453}DD7678$$

$$+\underset{(3.385)}{0.0241}(D81 + D88 + D94) - \underset{(-7.393)}{0.0851}D73$$

$R^2 = 0.982, \quad Adj\,R = 0.976, \quad D.W. = 1.044, \quad Sample: 1972:1994$

(2-4) Producer's Price Index (1990 = 100)

$$\Delta \log WPI_t = \underset{(-5.648)}{-0.0236} + \underset{(9.744)}{0.4819}\Delta \log PGDP_t + \underset{(20.43)}{0.4972}\Delta \log(PM_t \times ER_t) + \underset{(6.181)}{0.1606}\Delta \log WPI_{t-1} - \underset{(-11.44)}{0.1608}D73$$

$$+0.0423(D74+D89)+0.0222(D88+D94)-0.0199(D78+DD8384)$$
(6.048) (3.304) (-3.552)

$R^2=0.995$, $Adj\,R^2=0.993$, $D.W.=2.421$, $Sample: 1972 : 1994$

3. Supply Side

(3-1) Potential GDP (Billion won at constant prices)

$$\log PTGDP_t = -5.8515+0.3043\log(MORIB_t \times KSTRD_t)+(1-0.3043)\log(YDAYB_t \times EMPDN_t)+0.2097\log RDSTK_t$$

(3-2) Capital Stocks (Billion won at constant prices)

$$KSTRD_t = KSHRD_t + KSQRD_t$$

(3-2-1) Capital Stocks in Construction (Billion won at constant prices)

$$KSHRD_t = KIHRD_t + (1-\delta_H)KSHRD_{t-1}$$

where $\delta_H = 0.105744 \quad \forall 1968 \sim 1977; \quad = 0.093604 \quad \forall after 1978$

(3-2-2) Capital Stocks in Plants and Equipments (Billion won at constant prices)

$$KSQRD_t = KIQRD_t + (1-\delta_Q)KSQRD_{t-1}$$

where $\delta_Q = 0.119120 \quad \forall 1968 : 1977; \quad = 0.147017 \quad \forall after 1978$

(3-3) R&D Stocks (Billion won at constant prices)

$$RDSTK_t = RDKPV_t + RDKPB_t$$

(3-3-1) R&D Stocks in Private Sector (Billion won at constant prices)

$$RDKPV_t = RDIPV_{t-2} + (1-0.125)RDKPV_{t-1}$$

(3-3-2) R&D Stocks in Public Sector (Billion won at constant prices)

$$RDKPB_t = RDIPB_{t-3} + (1-0.125)RDKPB_{t-1}$$

4. Employment and Wages

(4-1) Rate of Unemployment (%)

$$UR_t = (1-EMPL_t / LF_t)\times 100$$

(4-2) Economically Active Population (Thousand persons)

$$LF_t = (LFPR_t / 100)\times POP15_t$$

(4-3) Participation Rate of Economic Activities (%)

$$LFPR_t = 18.4300+70.5381(EMPL_t / POP15_t)-6.1999(GDP_t / PTGDP_t)+0.1105LFPR_{t-1}+0.6714D76+0.4248DD7778$$
(7.553) (17.06) (-5.090) (2.092) (3.600) (2.807)

$$-0.5355D84$$
(-2.495)

$R^2 = 0.989, \quad Adj\,R^2 = 0.985, \quad D.W. = 1.895, \quad Sample: 1971: 1994$

(4-4) Number of the Employed (Thousand persons)

$$EMPL_t = EMPD_t + RDMN_t$$

(4-4-1) Number of the Employed in Non-R&D Sector (Thousand persons)

$$EMPD_t = 851.2525 - 1.7099(WGE_t \times 100 / CPI_t) + 257.2536(GDP_t / EMPD_t) + 0.8901 EMPD_{t-1} - 592.0327 DD8384$$
(1.157) (-1.368) (2.652) (10.54) (-4.344)

$R^2 = 0.997, \quad Adj\,R^2 = 0.996, \quad D.W. = 2.424, \quad Sample: 1973: 1994$

(4-4-2) Number of Researchers (Thousand persons)

$$RDMN_t = 8.2026 - 0.4145[RDWG_t /(12 \times WGE_t)] + 0.0125 RDI_t + 0.3347 RDMN_{t-1} + 3.9241 D82 - 2.7545(D88 + D91)$$
(6.332) (-5.221) (8.421) (3.440) (3.805) (-3.749)

$$-2.3267 DD7779 + 2.7229(DD8384 + D92)$$
(-3.343) (4.146)

$R_t = 0.999, \quad Adj\,R^2 = 0.999, \quad D.W. = 2.375, \quad Sample: 1973: 1994$

(4-5) Monthly Real Wage of Workers in Mining and Manufacturing (Thousand won)

$$\Delta \log(WGE_t \times 100 / PGDP_t) = 0.0468 + 0.3241 \log(GDP_t / PTGDP_t) + 0.2333 \Delta \log(WGE_{t-1} \times 100 / PGDP_{t-1})$$
(15.92) (10.92) (7.586)

$$-0.0244 D86 + 0.0931 D89 + 0.0526(D77 + D82) - 0.0465(D75 + D80 + D84) + 0.0314 D76$$
(-4.636) (18.01) (13.79) (-14.26) (5.563)

$$+0.0341(D88 + D92 + D94)$$
(10.50)

$R^2 = 0.993, \quad Adj\,R^2 = 0.987, \quad D.W. = 2.887, \quad Sample: 1975: 1994$

(4-6) Annual R&D Personnel Expenses per Research (Nominal, million won)

$$RDWG_t = 1564.962 + 0.6311 RDI_t + 0.7911 RDWG_{t-1} + 1514.872(D88 + DD9091) + 1076.009(D79 + D81 + D92)$$
(5.290) (3.212) (11.45) (6.548) (4.065)

$$-1213.445(D75 + D83 + D89) - 3383.167 D82$$
(-5.353) (-7.721)

$R^2 = 0.997, \quad Adj\,R^2 = 0.996, \quad D.W. = 2.052, \quad Sample: 1971: 1994$

5. Monetary Sector

(5-1) Demand for Money (M2) (Real, end of year, and billion won)

$$\log(M2_t \times 100 / PGDP_t) = -3.2004 - 0.0008(RCB_t - INFR_t) + 1.0290 \log GDP_t - 0.1783 LOG(CGR_t / CGE_t)$$
(-17.49) (-1.220) (16.89) (-3.385)

$$+0.1729 LOG(M2_{t-1} \times 100 / PGDP_{t-1}) + 0.0974 D82 + 0.0633(D77 + D83) + 0.0421(D89 + D94)$$
(3.361) (10.19) (10.13) (5.838)

$$-0.0222(D84 + DD9091) + 0.0271(D78 + D93)$$
(-4.073) (3.837)

$R^2 = 0.999, \quad Adj\,R^2 = 0.999, \quad D.W. = 2.340, \quad Sample: 1975: 1994$

(5-2) Yields of Corporate Bonds (%/year)

$$RCB_t/100 = \underset{(8.072)}{0.0645} + \underset{(7.051)}{0.0031INFR_t} - \underset{(-0.745)}{0.0296\Delta\log M2_t} + \underset{(9.590)}{0.4201(RCB_{t-1}/100)} + \underset{(8.741)}{0.0559DD7980} + \underset{(4.518)}{0.0299D91} - \underset{(-2.681)}{0.0180D93}$$

$$+\underset{(2.812)}{0.0122DD8890}$$

$R^2 = 0.990$, $Adj\,R = 0.984$, $D.W. = 2.572$, $Sample: 1976:\ 1994$

6. Foreign Trade

(6-1) Current Balance (BOP, million dollars at constant prices)

$$NCB_t = NTB_t + NNSB_t + NNTRB_t$$

(6-2) Trade Balance (BOP, million dollars at constant prices)

$$NTB_t = EXCB_t - IMCB_t$$

(6-2-1) Commodity Exports (BOP, million dollars at constant prices)

$$EXCB_t = \underset{(7.069)}{30410.19} - \underset{(-11.06)}{456.9291PX_t} + \underset{(31.16)}{39.8045IMW_t} - \underset{(-6.190)}{69.6440YEN_t} - \underset{(-13.59)}{12932.34(D80+D90)}$$

$$+\underset{(4.845)}{3415.308(DD8384+D88+DD9394)} - \underset{(-9.796)}{8005.843(D79+DD9192)} - \underset{(-4.825)}{4177.627(D78+D81)} - \underset{(-2.379)}{3062.018D89}$$

$R^2 = 0.999$, $Adj\,R^2 = 0.999$, $D.W. = 2.401$, $Sample: 1975:\ 1994$

(6-2-2) Commodity Imports (BOP, million dollars at constant prices)

$$IMCB_t = \underset{(-0.489)}{-342.1256} - \underset{(-2.558)}{0.0682(PMER_t)} + \underset{(23.32)}{0.2951GDP_t} - \underset{(-2.964)}{7.7616ER_t} + \underset{(13.54)}{0.4060IMCB_{t-1}} + \underset{(22.14)}{11577.58D94} + \underset{(9.119)}{4470.946D91}$$

$$-\underset{(-6.838)}{2184.301(D85+DD8889)} + \underset{(2.845)}{1093.735(D81+D83)}$$

$R^2 = 0.999$, $Adj\,R^2 = 0.999$, $D.W. = 3.126$, $Sample: 1978:\ 1994$

(6-3) Invisible Balance (BOP, million dollars at constant prices)

$$NSNB_t = (EXSNB_t + EXSFB_t) - (IMSNB_t + IMSFB_t)$$

(6-3-1) Non-Factor Income from Abroad (BOP, million dollars at constant prices)

$$EXSNB_t = \underset{(1.652)}{309.6481} + \underset{(43.30)}{0.1935EXCB_t} - \underset{(-2.557)}{1379.813D88} + \underset{(5.198)}{3103.929D94}$$

$R^2 = 0.993$, $Adj\,R^2 = 0.992$, $D.W. = 1.578$, $Sample: 1971:\ 1994$

(6-3-2) Non-Factor Income to Abroad (BOP, million dollars at constant prices)

$$IMSNB_t = \underset{(-4.104)}{-273.3275} + \underset{(9.983)}{0.0779IMCB_t} + \underset{(15.41)}{0.6987IMSNB_{t-1}} + \underset{(5.919)}{734.1928(D81+D89+D94)} - \underset{(-5.348)}{631.0724DD8587}$$

$$-\underset{(-3.071)}{430.4329(D84+D88)}$$

$R^2 = 0.999$, $Adj\,R^2 = 0.999$, $D.W. = 1.245$, $Sample: 1971:\ 1994$

(6-4) Export Prices (in dollars, 1990=100)

$$\log PX_t = \underset{(3.774)}{1.3769} + \underset{(4.180)}{0.2256}\log(WPI_t / ER_t) + \underset{(14.69)}{0.6469}\log PM_t + \underset{(4.973)}{0.1488}\log PX_{t-1} - \underset{(-17.75)}{0.1145}(D75 + DD8183)$$

$$-\underset{(-11.73)}{0.0898}(D80 + D8485) + \underset{(4.676)}{0.0583}D73 - \underset{(-4.689)}{0.0366}(D76 + D86)$$

$R^2 = 0.999$, $Adj\ R^2 = 0.999$, $D.W. = 1.650$, $Sample: 1971: 1994$

(6-5) Import Prices (in dollars, 1990=100)

$$\log PM_t = \underset{(15.34)}{4.1305} + \underset{(2.203)}{0.0757}\log(PWW_t) + \underset{(38.03)}{0.3548}\log PMO_t - \underset{(-10.54)}{0.3151}\log YEN_{t-1} + \underset{(11.13)}{0.1267}(D71 + DD8889) - \underset{(-5.375)}{0.0575}DD7678$$

$$+\underset{(5.753)}{0.0619}(D73 + DD9091)$$

$R^2 = 0.997$, $Adj\ R^2 = 0.996$, $D.W. = 2.065$, $Sample: 1973: 1994$

(6-6) Exchange Rates (won/US dollar)

$$\Delta \log ER_t = \underset{(9.560)}{0.0337} + \underset{(4.990)}{0.1237}\log(WPI_t / PWW_t) - \underset{(-5.244)}{0.1311}\log[(EXCB_t + EXSNB_t)/(IMCB_t + IMSNB_t)] + \underset{(8.573)}{0.1986}\Delta\log YEN_{t-1}$$

$$+\underset{(12.47)}{0.1554}D75 + \underset{(13.92)}{0.2693}D80 + \underset{(13.92)}{0.1693}D75 - \underset{(-10.43)}{0.0873}DD8889 + \underset{(5.900)}{0.0471}(D85 + D92) + \underset{(3.115)}{0.0320}DD8182$$

$R^2 = 0.991$, $Adj\ R^2 = 0.984$, $D.W. = 2.252$, $Sample: 1975: 1994$

7. Finance

(7-1) Government Deficits (Billion won at current prices)

$$GBB_t = CGR_t - CGE_t$$

(7-1-1) Government Revenues (Billion won at current prices)

$$CGR_t = TXR_t + RGE_t + RGO_t$$

(7-1-1-1) Tax Revenues (Billion won at current prices)

$$TXR_t = \underset{(0.249)}{40.6779} + \underset{(113.1)}{0.1453}(GDP_t \times PGDP_t / 100)$$

$R^2 = 0.998$, $Adj\ R^2 = 0.998$, $D.W. = 1.930$, $Sample: 1971: 1994$

(7-1-2) Government Expenditures (Billion won at current prices)

$$CGE_t = \underset{(1.107)}{133.3477} + \underset{(12.10)}{0.1202}(GDP_t \times PGDP_t / 100) + \underset{(7.490)}{0.4413}CGE_t - \underset{(-17.19)}{7463.784}D94 - \underset{(-8.779)}{1632.631}DD8388 + \underset{(3.902)}{1043.913}DD8081$$

$R^2 = 0.999$, $Adj\ R^2 = 0.999$, $D.W. = 1.780$, $Sample: 1971: 1994$

APPENDIX B: LIST OF VARIABLES

1. Endogenous Variables

CGE	Expenditures of Central Government (Billion won at current prices)
CGR	Revenues of Central Government (Billion won at current prices)
CPI	Consumer Price Index (1990=100)
CRD	Gross Consumption Expenditures in Non-R&D Sector (N/A, billion won at constant prices)
CPVRD	Private Consumption Expenditures in Non-R&D Sector (N/A, billion won at constant prices)
DPI	Disposable Income (N/A, billion won at constant prices)
EMPD	Number of the Employed in Non-R&D Sector (Thousand persons)
EMPDN	Number of the Employed at the Natural Rate of Unemployment (Thousand persons)
EMPL	Number of the Employed (Thousand persons)
ER	Exchange Rates (won/US dollar)
EX	Exports of Goods and Services (N/A, billion won at constant prices)
EXC	Commodity Exports (N/A, billion won at constant prices)
EXCB	Commodity Exports (BOP, million dollars at constant prices)
EXSN	Non-Factor Income from Abroad (N/A, billion won at constant prices)
EXSNB	Non-Factor Income from Abroad (BOP, million dollars at constant prices)
GBB	Government Deficits (Billion won at current prices)
GDP	Gross Domestic Product (N/A, billion won at constant prices)
IM	Imports of Goods and Services (N/A, billion won at constant prices)
IMC	Commodity Import (N/A, billion won at constant prices)
IMCB	Commodity Import (BOP, million dollars at constant prices)
IMSN	Non-Factor Income to Abroad (N/A, billion won at constant prices)
IMSNB	Non-Factor Income to Abroad (BOP, million dollars at constant prices)
INFR	Rate of Inflation (%)
KIHRD	Construction Investment in Non-R&D Sector (N/A, billion won at constant prices)
KIRD	Gross Fixed Capital Formation in Non-R&D Sector (N/A, billion won at constant prices)
KIQRD	Plant/Equipment Investment in Non-R&D Sector (N/A, billion won at constant prices)
KSQRD	Capital Stocks in Plant and Equipment (Non-R&D) (Billion won at constant prices)
KSHRD	Capital Stocks in Construction (Non-R&D) (Billion won at constant prices)
KSTRD	Capital Stocks in Non-R&D Sector (Billion won at constant prices)
LF	Economically Active Population (Thousand persons)
LFPR	Participation Rate in Economic Activities (%)
M2	Money Supply (End of year, billion won)
NSNB	Invisible Balance (BOP, million dollars at constant prices)
NTB	Trade Balance (BOP, million dollars at constant prices)
PGDP	GDP Deflator (1990=100)
PM	Import Price Index (Commodities, in dollars, 1990=100)
PTGDP	Potential GDP (Billion won at constant prices)
PX	Export Price Index (Commodities, in dollars, 1990=100)
RCB	Yields of Corporate Bonds (Average, %)
RDI	R&D Investment (Billion won at constant prices)
RDIPV	Private R&D Investment (N/A, billion won at constant prices)
RDKPB	Public R&D Stocks (Billion won at constant prices)
RDKPV	Private R&D Stocks (Billion won at constant prices)
RDMN	Number of researchers (Thousand persons)

RDSTK	R&D Stocks (Billion won at constant prices)
RWG	Monthly Wage of Workers in Mining and Manufacturing (thousand won at constant prices)
RDWG	Annual R&D Personnel Expenses per Researcher (million won at current prices)
TXR	Tax Revenues (Billion won at current prices)
UR	Rate of Unemployment (%)
URSTR	Natural Rate of Unemployment (%)
WGE	Monthly Wage of Worker in Mining and Manufacturing (Thousand won at current prices)
WPI	Producer's Price Index (1990=100)

2. Exogenous Variables

BCP	Construction Permits (10 thousands square meters)
CPBRD	Government Expenditures in Non-R&D Sector (N/A, billion won at constant prices)
EXSFB	Factor Income from Abroad (BOP, million dollars at constant prices)
IMSFB	Factor Income to Abroad (BOP, million dollars at constant prices)
IMW	Imports of OECD (Billion dollars at constant prices)
KINV	Inventories (N/A, billion won at constant prices)
LDBC	Commercial Banks' Investment Fund for Plants and Equipments (End of year, billion won)
MORI	Manufacturing Operation Ratio Index (1990=100)
MORIB	Average Manufacturing Operation Ratio Index (1990=100)
NNTRB	Transfer Balance (BOP, million dollars at constant prices)
PMO	Prices of Crude Petroleum (in dollars, 1990=100)
POP15	Population above 15 (Thousand persons)
PWW	GDP Deflator of OECD (1990=100)
RDIPB	Public R&D Investment (N/A, billion won at constant prices)
RGE	Net Revenue of Government Owned Corporate (Billion won at current prices)
RGO	Other Government Revenues (Billion won at current prices)
SDI	Statistical Discrepancies (N/A, billion won at constant prices)
YDAY	Annual Workdays in Mining and Manufacturing (12×monthly workdays, days)
YDAYB	Average Annual Workdays in Mining and Manufacturing (days)
YEN	Yen per US Dollar (Yen/Dollar)
D_{ij}	Dummy, ij=1, for year ij; otherwise=0
DD_{ijst}	Dummy, ij-st=1 for year ij-st; otherwise=0