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EFFECTS OF GOVERNMENT R&D ON ECONOMIC GROWTH: A MACRO-ECONOMIC MODEL FOR MEASUREMENT

March 1998

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This discussion paper has been prepared for use in discussions within NISTEP and for soliciting opinions from related researchers. The opinions expressed in this discussion paper are solely those of the author.

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1. Introduction

In Japan, "quick doubling" of government R&D investment has been one of the major issues in science and technology policy in recent years. In the "Science and Technology Basic Plan" decided on by the Cabinet in July 1996, a numerical target of "making the total size of science and technology related expenses from fiscal 1996 to fiscal 2000 approximately 1.7 trillion yen" was introduced to achieve this. Considering the fact that the enjoyment of external economies given by the nature of science and technology as public goods has been indispensable to the economic growth of Japan, with it already having been a long time since Japan was called a technological superpower, the ratio of government R&D spending in the economies of the advanced western countries should be the made the target for effort for now. "Doubling" should have more meaning than simple policy positioning.

On the other hand, while the direct goal of the country investing in science and technology is not the achievement of a certain degree of economic growth, how much of an economic effect can be obtained in the future by government R&D investment, which is being boosted despite the severe fiscal situation, must be a matter of concern to many citizens and policy-makers. This is because if the accelerated public investment in science and technology does not give rise to sufficient additional economic growth, a bottleneck will be encountered in just securing the funding for continuing reinvestment in science and technology.

This study deals with this policy issue by constructing a simultaneous equation model (macro-economic model) for predicting the economic effect of government R&D investment.[1)] As is well known, a simultaneous equation model is comprised of a set of probabilistic models defining cause-and-effect relations of various economic variables and has been used for a long time now in the field of economic policy as a tool for prior evaluation of policy and decision making. So far as the writer knows, however, only rare attempts have been made to design a model focusing on the process by which R&D produces endogenous economic growth such as intended by this study.

Of course, R&D is a type of economic activity with a high degree of uncertainty, so it is extremely difficult to predict its economic effects by probabilistic models. Not only is prediction of the probability of success of R&D inherently difficult, but also there are various uncertain factors at work in the process by which their results produce value when successful. The degree of uncertainty becomes even higher in basic and scientific research handled at the national level. While limited in this way, there is the major advantage that a simultaneous equation model enables description of the dynamic interaction of various policy variables. Therefore, it can be expected to be useful as a tool for testing out thinking when drafting science and technology policy.

Below, first the related prior research will be reviewed, then a report made on the structure of the model prepared, the data used, the performance of the model, etc. Further, the model will be used for predictive simulation of the economic effects in the case where the numerical target of the "Science and Technology Basic Plan" is realized and some thoughts given on the results of the prediction and future research issues.

2. Prior Research

As explained above, little research has been performed using simultaneous equation models. Numerous studies have been made however on the economic effects of R&D investment. There have also been some attempts at research dealing with the government sector.

Empirical studies on the profitability of R&D investment began with the case study analysis of Griliches (1957). After that, the variable of the R&D stock (also called "technological knowledge stock"), estimated from R&D spending, was introduced into aggregate production functions and the increase in output due to increases in R&D stock frequently measured. Terleckyj (1980) used data of 20 manufacturing industries to construct linear homogeneous Cobb-Douglas type production functions during which he divided the variable of the R&D stock, introduced as a shift parameter, into R&D performed in these industries and spending embodied in capital goods and intermediate goods purchased from other industries and further classified funds as either private funds or public funds. That is, this analysis experimented with the measurement of the profitability of R&D commissioned from the government to the industrial sector. The findings indicated that the effect of government funds on the output of R&D is not statistically significant. Note that in actual measurement, the variable expressing the net increase of the R&D stock is represented by the amount of R&D spending.

Levy and Terleckyj (1983) took the approach that the main effect of government R&D is the inducement of private sector R&D investment through commissioned research. This was verified by a multiple regression model using macro-economic data. This analysis found that research commissioned by the government induces 27 cents of private R&D spending per dollar. The parameter for non-commissioned government R&D investment was however concluded to be not statistically significant.

While the empirical research of Levy et al. showed that government R&D, conducted as commissioned research, induces private sector R&D spending, generally an increase of government spending is considered to possibly crowd out private investment due to the accompanying increase in government borrowing and rising interest rates. As an analysis relating to this point, the study by Carmichael (1981) may be mentioned. Carmichael conducted a study using data from 47 companies and concluded that the phenomenon of government commissioned research crowding out private R&D spending is extremely small.

These studies have the common feature that they mainly focus on research commissioned to the private sector in analyzing the economic effects of government R&D investment and do not cover the effects of government R&D investment as a whole. The reason why they have dealt solely with commissioned research is that the economic effects of government R&D spending, much of which is allocated to basic research, has been considered not to contribute directly to productive activities, but to have indirect effects such as inducing private sector R&D. For example, Mowery (1994) argued that since the economic effect of government investment in basic research is not a direct effect leading to output, but an indirect effect of raising the profitability of applied R&D, it is unsuitable to use a framework of cost-benefit analysis in dealing with the same. On the other hand, as seen in the empirical study of Mansfield (1980), since there are analytical findings showing that there is strong correlation between basic research and productivity, while using data of the manufacturing industries, the direct effects on productive activities of even government R&D investment should not be excluded a priori but must be discussed empirically.

The recent empirical research of Mamuneas and Nadiri (1996) was a rare attempt to study both the direct effect of government R&D investment on output and the indirect effect of inducing private R&D. It used a framework of cost functions to analyze the effects of the R&D tax system and government R&D investment on the growth of output in the American manufacturing industries and private R&D investment using sector-wise data of two-digit industrial classifications. According to the findings, in industries with a low R&D intensity, there is a substitution relation between R&D conducted at government expense and R&D conducted at private expense, so while an increase in government R&D conducted reduces unit costs, it also crowds out R&D private investment. Further, tax deductions and immediate depreciation of R&D facilities are remarkably effective in inducing R&D investment in the private sector. That is, R&D investment conducted at government expense is effective in improving cost efficiency and promoting production growth, while policies on the R&D tax system are suitable means in promoting R&D investment in the private sector. To maintain balanced growth, it is considered necessary to find the optimum mix of the two policy means.

In Japan, Wakasugi (1983) conducted an analysis using a framework of production functions and constructed a model considering as explanatory variables of total factor productivity the R&D stock of private companies, the R&D stock due to the importation of technology, and government R&D stock. The findings indicated that the profitability of the government R&D stock was negligibly low. He added as his explanation of this point that R&D at government research institutes and nonprofit research institutes do not immediately lead to profit, but create a favorable environment for the R&D activities of private companies. Note that Miyakawa (1983) has pointed to problems in this analysis such as the failure to take into account the time lag from R&D spending to technical progress.

As explained above, most previous empirical studies have analyzed the relationship of R&D stock and output using a framework of production functions (or cost functions) based on neoclassical economic theory. In recent years, various attempts have been made to use other methods to investigate the influence of government R&D investment. For example, Cockburn and Henderson (1997) attempted to determine the effect of public research investment on the pharmaceuticals industry by measuring the relation between the two by the number of joint works of researchers in companies and researchers in the public sector in scientific papers in that field and found that a high degree of relation contributed to an improvement of productivity in research activities in the private sector. Jaffe, Fogarty, and Banks (1997) conducted an analysis using data on citations of prior patents in patent applications for inventions as an indicator of the impact of government organizations on research activities and found that along with activity to commercialize the technology turned out by government organizations, the number of citations of patents owned by NASA and other research organizations increased. Further, Feldman and Lichtenberg (1997) analyzed the relationship between public research investment and private research investment by using data on the number of organizations in Europe by country and field and reported that the manufacturing companies and service related companies in each country tended to specialize in the same scientific fields as universities and public institutions in those countries. The various scientific and technical indicators used in these studies are expected to have broader possibilities for use in economic analyses of government R&D investment. At the present point of time, however, no methodology has yet been established for tying these in with a quantitative determination of economic effects.

Now, the empirical studies conducted up to now, whether covering the direct effects or indirect effects of government R&D, have been conducted focusing on construction of single models (and their variations). Therefore, while the findings have contributed much to improved understanding of the specific areas covered, the problem has remained of poor indicators for policy and a comprehensive evaluation of the economic effects of government R&D investment. This study deals with this issue by including production functions taking in account the direct effects of knowledge stock produced by government R&D investment in the production block, attempting to construct simultaneous equations incorporating a model relating to various indirect effects as well, and applying the same to policy simulations.

3. Structure of Model and Method of Measurement of Knowledge Stock

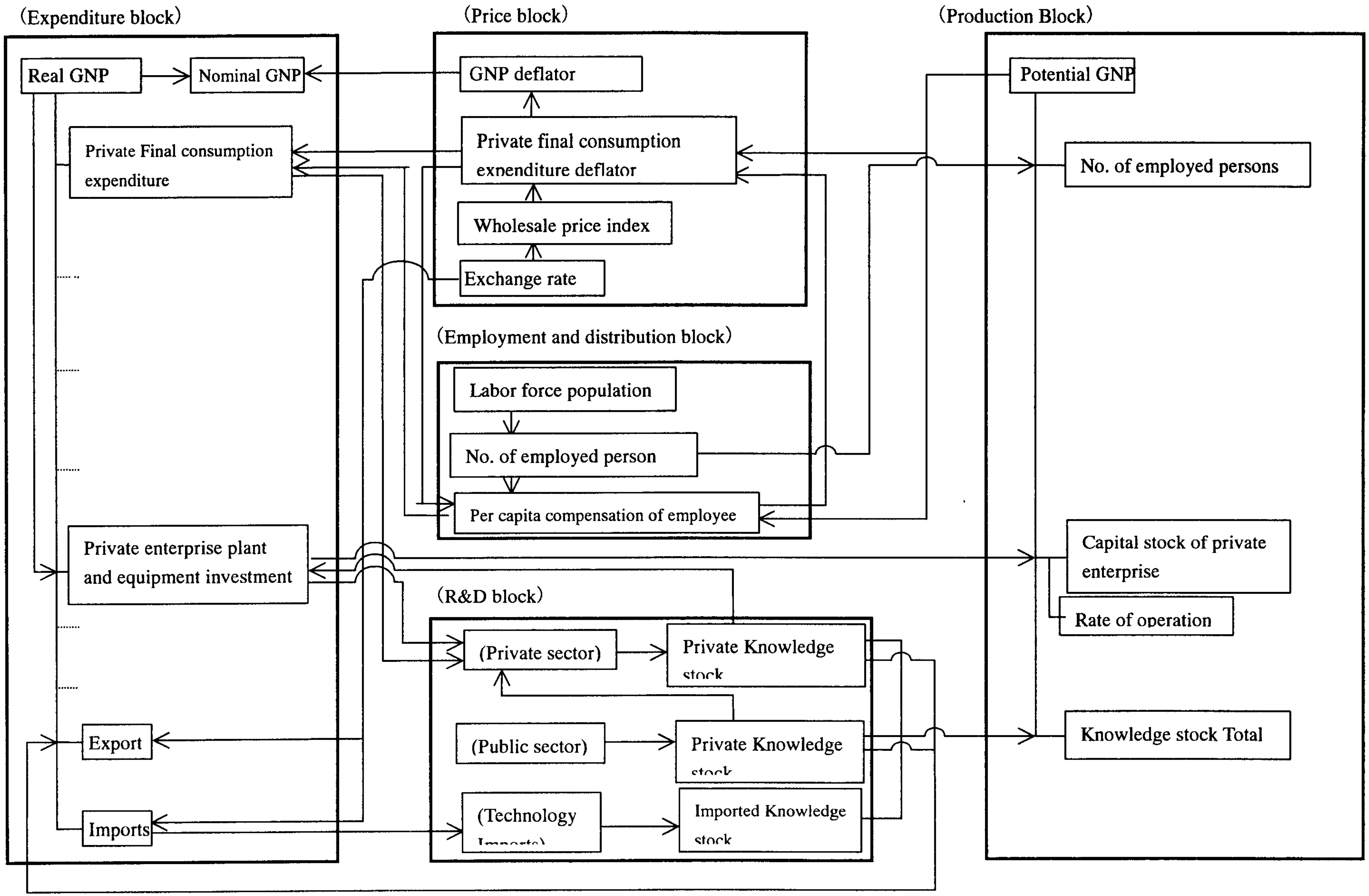
This section discusses the structure of the macro-economic model developed based on the above perception of the issues and the variable of a "technological knowledge stock" forming the central concept in discussions of the relation between R&D and economic growth.

(1) Structure of Model and Data Used

The macro-economic model developed here is comprised of five blocks: "expenditure block", "production block", "price block", "employment and distribution block", and "R&D block" and includes a total of 34 simultaneous equations and 46 variables (of which, 34 are endogenous variables and 12 are exogenous variables). The measurement period differs somewhat by equation, but generally covers the early 1970s to 1994 or 1995. The parameters were estimated by using the restricted least squares method for the construction of production functions and by the ordinary least squares method for all the others.

The model is of a standard type including the ordinary Keynesian model in the expenditure block, but has several special features. These points are explained along with the framework of the model shown in Fig. 1.

Fig. 1. Flow Model (Summary)



The production block of the model incorporates Cobb-Douglas type production functions. Employed persons, input factors in production, are determined by the employment and distribution block, capital stock of private enterprise by the expenditure block, and knowledge stock by the R&D block. The potential GNP (potential production) is estimated by the equations for estimation of the production functions setting the operating rate of the capital stock as the upper limit. The potential GNP determines the explanatory variables of the consumption function, that is, the employees income and consumption expenditure deflator and thereby influences private final consumption expenditure. Therefore, this model is set up so that determination of demand far over the possibilities of production is not possible.

The biggest feature of this model is the incorporation of a R&D block to describe the process of endogenous growth produced by R&D. The R&D block is comprised of three sectors: the private sector, public sector, and technology imports. The variables of the private knowledge stock, public knowledge stock, and imported knowledge stock are estimated from each sector by the later defined method. The total of these knowledge stocks is introduced into the production functions so as to describe the direct effect of R&D on output.

Further, in this model, the knowledge stock is assumed to not only have a direct effect of enhancing potential supply capabilities, but also to have the following indirect effects:

1) Private knowledge stock induces private enterprise plant and equipment investment in the process of being commercialized.

2) Public knowledge stock induces plant and equipment investment in private R&D through the spillover effect to the private sector.

3) Private knowledge stock and public knowledge stock enhance international competitiveness in industry and increase exports.

Note that the "private R&D investment" spoken of here means research expenses used by companies, private research institutes, and private universities, while public R&D investment means research expenses used by central government-owned and local government-owned research institutes, government-affiliated agencies and research institutions, and national and public universities.

The findings of the construction of production functions alluded to here are discussed in detail in section 4, while the findings of construction of the model of the indirect effects of knowledge stock are taken up in section 5. See material (1) for the data used for the construction, while see materials (2) and (3) for the details on the simultaneous equations.

(2) Method of Measurement of Knowledge Stock

The technological knowledge stock is measured by the following equation:[2)]

$R_t = RF_t + (1-\delta) * R_{t-1}$ . . . . . ①

where, R_t: technological knowledge stock in time t

RF_t: technological knowledge flow in time t

δ : Rate of obsolescence of technological knowledge

The "technological knowledge flow" spoken of here is not the R&D investment of the time, but the result of R&D investment made in the past realized in that time through a gestation period (R&D lag).

Note that the technological knowledge stock of the benchmark year is found as follows: Equation ① may be changed to

$RF_t = R_t - (1-\delta) * R_{t-1}$

$= \{(R_t / R_{t-1} - 1) + \delta\} * R_{t-1}$

From this,

$R_{t-1} = RF_t/(g + \delta)$

where, g: growth rate of R

Here, assuming that the growth rate of the stock and the growth rate of the flow are equal, the technological knowledge stock in the benchmark year (tb) becomes:

$R_{tb} = E_{tb+1}/(g + \delta)$ .... ②

where, E_{tb+1}: R&D investment in time tb+1

Of the data required when estimating the technological knowledge stock by the above method, yearly data on R&D investment is available from the Management and Coordination Agency, Kagaku gijutsu kenkyu chosa (Survey of Research and Development), but there is only ad hoc survey data on the rate of obsolescence of technological knowledge and the R&D lag. Here, as relatively recent survey data, reference was made to the Economic Research Institute of the Japan Society for the Promotion of Machine Industry and the Mitsubishi Research Institute (1991) and the rate of obsolescence and the time lag set as shown in Table 1.[3)]

Note that the flow with respect to imported knowledge stock is not the R&D investment, but the payments made for the cost of importation of technology. This differs from R&D investment in that it is payment made along with introduction of finished technology, so the lag until embodiment to knowledge stock is 0 years, but obsolescence is assumed to proceed at the same pace as with private knowledge stock.

Table 2 shows the data of the estimated knowledge stock. In the estimation, the data on the R&D investment and payments made for the cost of technology imports is converted to real terms by an R&D deflator based on 1990. Since there is almost no difference among sectors in the rate of obsolescence assumed as a premise when estimating the knowledge stock, the differences in growth in flow are reflected substantially as is in the growth of the stock in each sector. R&D investment in companies, included in the private sector, grew particularly fast in the 1980s, so there was a remarkable increase in the private knowledge stock starting in the late 1980s as shown in Fig. 2. On the other hand, the public knowledge stock and imported knowledge stock remained fairly level. Therefore, in the sectoral shares shown in Fig. 3, clearly the share of the private sector in the total knowledge stock increased. The share of the private knowledge stock was 60% in 1972, but reached 80% in 1995.

4. Measurement of Direct Effect of Knowledge Stock by Production Function Model

This section analyzes the direct effect of R&D on output based on the results of an estimate by the production function model.

(1) Results of Estimate by Production Function Model

Hicks-neutral technological change was assumed and the following expanded linear homogeneous Cobbs-Douglas type production function was introduced into the production block of this model. [4)]

$Y = A(\rho K)^{\alpha} L^{1-\alpha} R^{\gamma}$ ...... ③

where, Y: Real GNP

A: Constant

ρ: Operating rate index

K: Real capital stock of private enterprise

L: Number of employed persons

R: Total technological knowledge stock

The log of the two sides of equation ③ was taken and the parameters estimated by the restricted least squares method. The results are shown below:

$$\ln Y = -1.398 + 0.301041 \ln(K) + 0.698959 \ln(L) + 0.164190 \ln(R)$$

$$(-5.87)\ (8.70) \qquad (20.21) \qquad (5.55)$$

Estimation period: 1973 to 1994

R^2=0.9981, DW=1.376, figures in parentheses are t values

Table 1. Premises of Estimation of Knowledge Stock

	Private knowledge stock	Public knowledge stock	Imported knowledge stock
Rate of obsolescence	10.20%	10.30%	10.20%
Time lag	4 years	8 years	0 year

Note: Set with reference to Economic Research Institute of the Japan Society for the Promotion of Machine Industry and Mitsubishi Research Institute (1991).

Table 2. Trends in Knowledge Stock

(Unit: million yen)

	Private knowledge stock	Public knowledge stock	Imported knowledge stock	Total
1972	11795417	6041784	1932220	19769421
1973	13236506	6106871	2131722	21475099
1974	15052227	6239412	2208636	23500275
1975	16840829	6429328	2273460	25543617
1976	18698715	6683885	2319906	27702507
1977	20490526	6972506	2364855	29827887
1978	22108917	7364537	2399189	31872643
1979	23593617	7842696	2475356	33911669
1980	25034930	8381969	2519684	35936583
1981	26478195	8890111	2572499	37940806
1982	28033148	9267909	2636825	39937882
1983	29691458	9675695	2685593	42052747
1984	31577176	10044244	2722654	44344073
1985	33851416	10422218	2763610	47037244
1986	36298900	10897687	2771573	49968161
1987	39081012	11360906	2801506	53243424
1988	42096358	11777415	2852169	56725942
1989	45665799	12208076	2901728	60775602
1990	49323392	12597948	2977658	64898999
1991	53070339	12985026	3062001	69117366
1992	57068535	13368536	3154675	73591746
1993	61410784	13791678	3188755	78391217
1994	66159674	14281362	3224801	83665837
1995	70815987	14889668	3276177	88981832

Notes: Real values based on R&D deflator (1990=100).

Fig. 2. Trends in Knowledge Stock

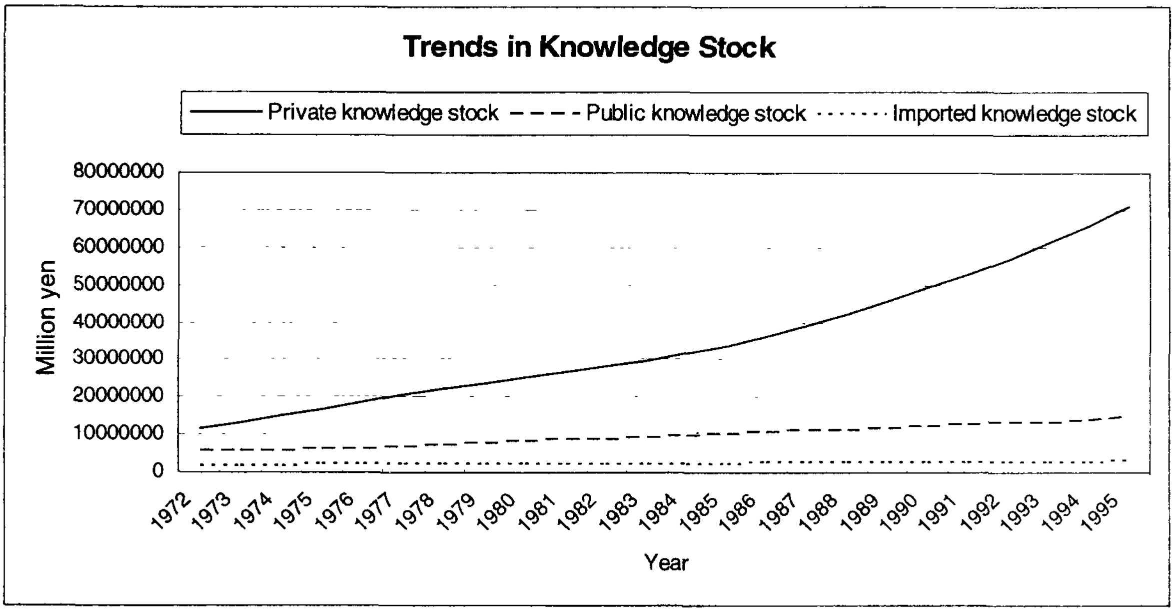
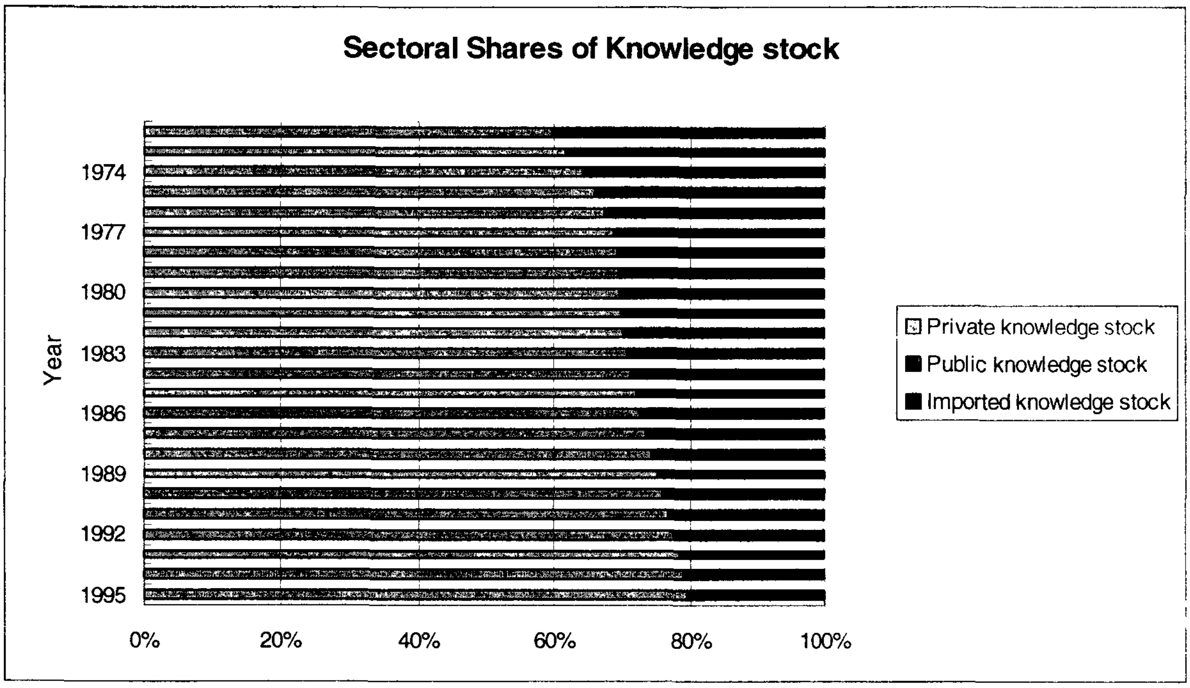


Fig. 3. Sectoral Shares of Knowledge Stock



The parameters are all statistically significant and the coefficients of determination extremely high. The value of the Durbin-Watson ratio indicates that the conclusion of the validation of the hypothesis relating to the first stage auto-correlation is reserved, but compared with the prior research, the fitness of the model shown by the results of the estimate was good.

(2) Degree of Contribution of Knowledge Stock to Economic Growth

Next, an analysis will be made of the contribution of the knowledge stock to economic growth using the production function model constructed.

If equation ③ is partially differentiated for time, the following equation is obtained:

$$\dot{Y}/Y = \alpha \cdot (\rho \dot{K})/(\rho K) + (1-\alpha) \cdot \dot{L}/L + \gamma \cdot \dot{R}/R \ \ldots\ldots \text{④}$$

The items on the right side of equation ④ indicate the degree of contribution to growth of Y.

Table 3 shows measurements of the average annual degrees of contribution of each explanatory variable on the real GNP growth rate for each of the late 1970s, early 1980s, late 1980s, and early 1990s using estimated parameters and the calculation of the rates of contribution using the growth rate as 100. Figure 4 graphs the results of measurement of the degrees of contribution.

The average annual real economic growth rate fell from the 4.6 percent of the late 1970s to 3 percent in the early 1980s and then returned once again to the high level of 4.6 percent in the late 1980s, but dropped tremendously to the level of 2 percent in the early 1990s and thereby drew a cyclic pattern of fluctuation. During that period, the degree of contribution of capital to economic growth was highest in the late 1970s, but subsequently fell steadily to the early 1990s. The degree of contribution of labor gradually increased until the late 1980s, but fell to the level below that of the late 1970s in the early 1990s. The degree of contribution of the knowledge stock dropped from the late 1970s to the early 1980s, then held fairly steady, but rose remarkably in relative importance due to the slow growth in the degrees of contribution of other input factors and in the early 1990s became the largest growth factor of all.

5. Indirect Effects of Knowledge Stock

As explained above, in this macro-economic model, the knowledge stock is assumed to not only have a direct effect on output, but also three indirect economic effects. In this section, a report is given on the results of construction of a model relating to various hypotheses.

(1) Effect of Private Knowledge Stock on Inducing Private Enterprise Plant and Equipment Investment

The model of the private enterprise plant and equipment investment (investment function) hypothesizes that plant and equipment investment is induced in the process of private knowledge stock being commercialized. First, an equation is constructed adding private knowledge stock as an explanatory variable to the acceleration principle type investment function as follows:

Real private enterprise plant and equipment investment

=-1894.87+0.534470 (increase in real GNP over previous year)

(-1.17) (6.20)

+0.000107 (private knowledge stock)

(1.66)

+0.874633 (real private enterprise plant and equipment investment of previous period)

(15.44)

+3177.46 (1988-1990 dummy)

(1.87)

Estimation period: 1974 to 1995

R^2=0.9914, figures in parentheses indicate t values

Table 3. Contribution of Production Factors to Economic Growth

(1) Average Annual Degree of Contribution

(Unit: %)

	Real GNP growth rate	Capital stock	Number of employed persons	Knowledge stock
1975-1979	4.62	2.70	0.69	1.23
1980-1984	3.06	1.59	0.66	0.81
1985-1989	4.64	2.47	0.98	1.19
1990-1994	1.94	0.60	0.51	0.83

Note: Estimation error eliminated to normalize data.

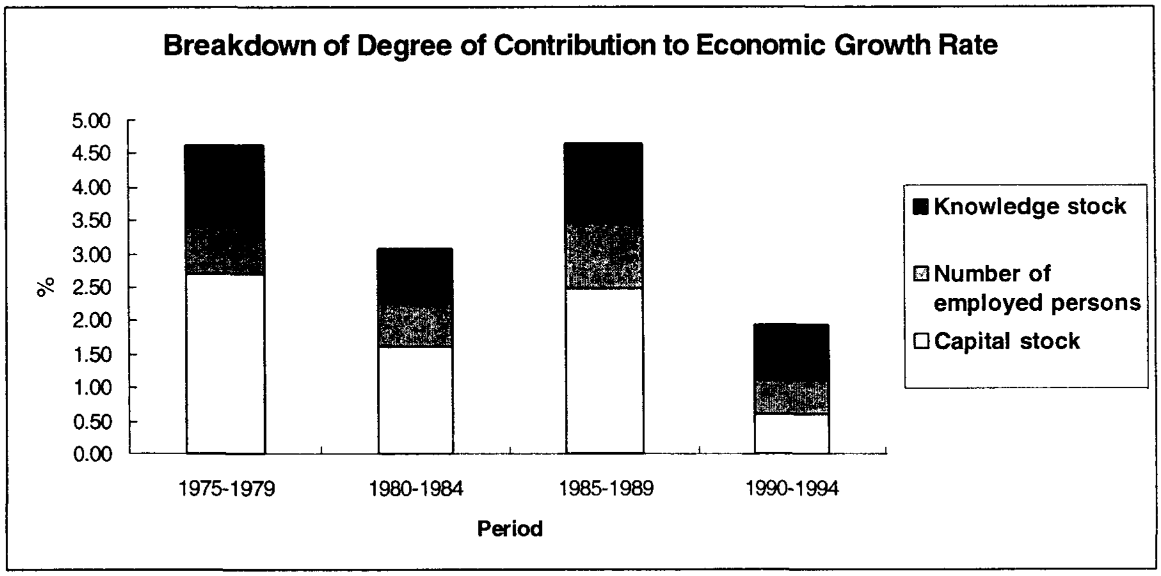
(2) Average Annual Rate of Contribution

(Unit: %)

	Real GNP growth rate	Capital stock	Number of employed persons	Knowledge stock
1975-1979	100.00	58.44	14.94	26.62
1980-1984	100.00	51.96	21.57	26.47
1985-1989	100.00	53.23	21.12	25.65
1990-1994	100.00	30.93	26.29	42.78

Note: Estimation error eliminated to normalize data.

Fig. 4. Breakdown of Degree of Contribution to Economic Growth Rate



Private enterprise plant and equipment investment rose remarkably from 1988 to 1990, fell starting in 1992 and returned to the level of 1988 in 1994. This portion of fluctuation was absorbed by the annual dummy variable.

The fitness of this model is high, but the parameter of the private knowledge stock is unstable and the t value is at a level not enabling the null hypothesis to be rejected at a 5 percent level of significance. If the log of the private knowledge stock is taken, however, as shown by the following result of estimation, the parameter of the variable becomes significant at the critical region 5 percent level.

Real private enterprise plant and equipment investment

=74452.2+0.485197 (increase of real GNP over previous year)

(-1.95) (5.38)

+4485.61 LOG (private knowledge stock)

(1.88)

+0.860771 (real private enterprise plant and equipment investment of previous period)

(14.96)

+3264.34 (1988-1990 dummy)

(2.06)

Estimation period: 1974-1995

R^2=0.9914, figures in parentheses indicate t values

The results of estimation of the investment function were adopted for this macro-economic model.

Note that to explain the effect of business fluctuations as explained above, an attempt was made to construct a capital stock adjusted type investment function including a demand-supply gap (potential GNP/real GNP) in the explanatory variables, but the decision was made to use the above results of estimation after comparing the fitness of the models.

(2) Effect of Public Knowledge Stock on Inducing Private R&D Investment

As explained in section 2, several previous studies took note of the effect of government R&D in inducing R&D investment in the private sector. In this model as well, the indirect effects were considered and the following equation constructed including the public knowledge stock in the explanatory variables of private R&D plant and equipment investment.

Real private R&D plant and equipment investment

=7066654

(6.09)

+31252.9 (real private R&D plant and equipment investment of previous period/real private enterprise plant and equipment investment of previous period)

(4.38)

-7623487 (demand and supply gap of previous period)

(-7.06)

+0.116075 (public knowledge stock)

(15.43)

Estimation period: 1975-1995

R^2=0.9500, figures in parentheses indicate t values

Here, the thinking is adopted that private R&D plant and equipment investment is basically governed by the ratio of R&D plant and equipment investment in the total plant and equipment investment of the previous period. This variable is stable since total plant and equipment investment and R&D plant and equipment investment are similar in movement. A separate variable becomes necessary for explaining the effect of business fluctuations. Therefore, the variable of the demand-supply gap of the previous period was introduced, whereupon as explained above, all of the parameters were significant and results of estimation with a high goodness of fit were obtained. A negative sign of the demand-supply gap means that R&D plant and equipment investment is suppressed in periods of business recession when potential supply capability exceed demand.

Judging from the results of estimation of this model, the hypothesis that government R&D investment induces private R&D investment is supported.

(3) Enhancement of International Competitiveness by Private and Public Knowledge Stock

This model assumes that private knowledge stock and public knowledge stock enhance international competitiveness and increase exports. With an export function using stock as an explanatory variable in addition to the exchange rate, relatively good results of estimation were obtained with the following logarithmic type model:

LOG (real exports and incomes from abroad)

=15.2832+0.382447 LOG (exchange rate)

(-8.80)(4.36)

+1.360.14 LOG (private knowledge stock + public knowledge stock)

(18.35)

Estimation period: 1973-1995

R^2=0.9866, DW=0.866, figures in parentheses indicate t values

This equation was used in this model, but the Durbin-Watson ratio of the above results of estimation was at a level not enabling the hypothesis of auto-correlation to be rejected. Room for improvement in the future remains.

6. Interpolation Test and Predictive Simulation

For the results of construction of equations other than the models reported up to the previous section, see Material (2) at the end of the paper. In this section, a report is made of the result of the interpolation test of a simultaneous equation system combining these equations. Further, an explanation is given of the results of a predictive simulation attempted relating to the economic effects in the case of the numerical target of the "Science and Technology Basic Plan" being realized.

(1) Interpolation Test

Ordinary interpolation tests (partial test, total test, and final test) were conducted on the developed macro-economic model to check the performance. The average rate of error for each variable according to the tests is shown in Material (4).[5]

The quality of the performance of the macro-economic model was finally judged referring to the rate of error obtained by the final test, but there is no statistical criteria for judgement concerning the range of allowance of the rate of error. According to Murota et al. (1992), the yardstick is that the rate of error be within 2 to 3 percent for major items like the GNP. In the final test of this model, the rate of error of the real GNP was just 1.89 percent, so it was judged that this model was suitable for medium and long term predictive simulation.

(2) Prediction of Economic Effects by Achievement of Target of "Science and Technology Basic Plan"

The current predictive simulation attempted to calculate the economic effect in the case of achievement of the target of "making the total size of science and technology related expenses from fiscal 1996 to fiscal 2000 approximately 1.7 trillion yen" of the "Science and Technology Basic Plan".

In this model, the research expense used by the public sector, an exogenous variable, is set by a nominal value by item. As shown in Table 4, an "augmentation case" where the total of the nominal research expenses of the public sector reaches about 1.7 trillion yen from 1996 to 2000 and the "trend case" where the growth rate of nominal research expenses follows the trend of the past 10 years and the total during the same period remains only approximately 1.54 trillion yen were set and a comparison made of trends in the real GNP starting from the year 2000 in the two cases.

Table 4. Premises of Government R&D Investment in Predictive Simulation

(1) Augmentation Case

(Unit: million yen)

	Total	Personnel expenses	Material expenses	Expenses for purchase of tangible fixed asset
1995	2879004	1258036	908962	712006
1996	2798179	1280156	965157	552866
1997	3064287	1318561	1109931	635796
1998	3365703	1358118	1276420	731165
1999	3707584	1398861	1467883	840840
2000	4095859	1440827	1688066	966966
2001	4306088	1484052	1802854	1019182
2002	4528239	1528573	1925448	1074218
2003	4763035	1574430	2056379	1132226
2004	5011242	1621663	2196212	1193366
2005	5273676	1670313	2345555	1257808
2006	5551205	1720423	2505053	1325729
2007	5844750	1772035	2675396	1397319
2008	6155294	1825196	2857323	1472774
2009	6483877	1879952	3051621	1552304
2010	6831610	1936351	3259131	1636128

Notes:

1. Figures up to 1996 are real figures from Management and Coordination Agency, Kagaku gijutsu kenkyu chosa (Survey of Research and Development).

2. The rate of growth of personnel expenses was fixed to 3%, the same as the trend case. The rates of growth of material expenses and expenses for purchase of tangible fixed assets were set as 15% for 1997 to 2000. By this, the total for 1996 to 2000 becomes about 1.7 trillion yen. Later, the same rates of growth as the trend case were set.

(2) Trend Case

(Unit: million yen)

	Total	Personnel expenses	Material expenses	Expenses for purchase of tangible fixed asset
1995	2879004	1258036	908962	712006
1996	2798179	1280156	965157	552866
1997	2932069	1318561	1030788	582721
1998	3073186	1358118	1100811	614188
1999	3221956	1398861	1175741	647354
2000	3378829	1440827	1255692	682311
2001	3544286	1484052	1341079	719156
2002	3718835	1528573	1432272	757990
2003	3903018	1574430	1529666	798922
2004	4097410	1621663	1633684	842063
2005	4302622	1670313	1744774	887535
2006	4519303	1720423	1863419	935462
2007	4748143	1772035	1990131	985977
2008	4989876	1825196	2125460	1039219
2009	5245281	1879952	2269992	1095337
2010	5515187	1936351	2424351	1154485

Notes:

1. Figures up to 1996 are real figures from Management and Coordination Agency, Kagaku gijutsu kenkyu chosa (Survey of Research and Development).

2. The rates of growth of the expense items were fixed to the average annual rates of growth of 1995 to 1994. That is, the rate of growth of personnel expenses was set to 3%, the rate of growth of material expenses was set to 6.8%, and the rate of growth of expenses for purchase of tangible fixed assets was set to 5.4%. In this case, the total for 1996 to 2000 becomes about 1.54 trillion yen.

Note that the premises of the other exogenous variables were set as follows. The labor force population was set with reference to the median estimate of the productive age population according to the Institute of Population Problems, Ministry of Health and Welfare, Nihon no shorai jinko suikei (Estimate of Future Population of Japan). The exogenous variables in the system of national accounts were set with reference to the trends in the past 10 years or so. That is, it was assumed that the real government final consumption expenditure would grow by a rate of 2.4 percent and the real public fixed capital formation by a rate of 3.2 percent and that the real private enterprise inventory investment would be 1 trillion yen a year and the real public enterprise inventory investment 0 yen a year. Further, the exchange rate was made the actual rates for 1996 and 1997 and then rates rising 1 yen a year from US$1=115 yen starting from 1997. The official discount rate was made the actual rates for 1996 and 1997 and then rates rising in stages of 0.5 percent to reach 2.5 percent in 2010.

In this model, since the time lag for R&D investment by the public sector to be embodied in knowledge stock was assumed to be eight years, the difference in public knowledge stock between the two cases appears after 2005. As shown in Table 5, the difference in public knowledge stock between the two cases starts growing in 2005 resulting in a difference of 2.43 trillion yen in 2010 between the about 27.2 trillion yen of the augmentation case and about 24.7 trillion yen in the trend case. Further, in 2009, four years after 2005, a difference will start to appear between the two cases in the knowledge stock due to private R&D induced by the public knowledge stock. The augmentation case of private knowledge stock in 2010 will exceed the trend case of about 60 billion yen. Note that in the imported knowledge stock, the stock of the trend case will slightly exceed the augmentation case starting in 2006. This is due to the difference in the deflators of the two cases. In the total of the knowledge stock in 2010, the augmentation case will exceed the trend case of about 2.49 billion yen.

This difference in the knowledge stock is reflected in the difference of the economic growth rate in the two cases. As shown in Table 6, the difference in the real GNP between the two cases will surface starting in 2005. By the year 2010, real GNP will reach about 762 trillion yen (3.4% real growth rate over the previous year) in the augmentation case, while will it would reach about 754 trillion yen (3.2% real growth rate over the previous year) in the trend case. That is, the realization of the numerical target given in the "Science and Technology Basic Plan" will raise the real economic growth rate around the year 2010 by 0.2 percent point and give rise to an additional real added value of about 8 trillion yen.

In the current simulation, when setting common values for both cases for exogenous variables other than public R&D investment, use was made of an optimistic scenario referring to past long term trends, therefore the economic growth rate for the year 2010 is a high level of over 3 percent even in the results of prediction by the trend case. When seen from the viewpoint of cost effectiveness, however, the difference in the two cases suggests a remarkable economic effect due to the expansion in public R&D investment.

That is, since the difference in public knowledge stock between the two cases in 2010 is about 2 trillion yen, the difference of 8 trillion yen in the real GNP corresponds to about four times that. Further, since the difference in total research expenses used by the public sector in the two cases from 1996 to 2000 is about 1.6 trillion yen, the results of the prediction suggest that this difference in nominal flow results in additional real added value of 8 trillion yen in just the one year of 2010 after the time lag of R&D. Considering this result of prediction, realization of the numerical target of the "Science and Technology Basic Plan" can be expected to give rise to a sufficiently large economic effect.

7. Considerations and Future Issues

In recent years, input of capital and labor in the Japanese economy has been remarkably stagnant. During the same period, however, growth in the knowledge stock has supported economic growth. In the early 1990s, an average annual growth of about 2 percent was maintained - though with difficulty. The increase in the knowledge stock supporting growth in the early 1990s was mainly due to the busy private sector R&D conducted in the 1980s embodied after a time lag. There was minus growth recorded in private sector R&D each year from fiscal 1992 to fiscal 1994. This makes it difficult to expect future economic growth from growth in the private knowledge stock. On the other hand, the main input factor of production, that is, labor, is expected to slow in growth in the future as well due to the stagnation in population. Further, there are frequent observations that growth in capital will stagnate due to the fall in the savings rate accompanying the higher proportion of senior citizens in the population.

To maintain a certain level of economic growth under this type of macro-economic environment, maintaining growth in the knowledge stock, which is a factor of growth, through expanded government R&D investment becomes essential. Government R&D requires a longer gestation period until embodiment into knowledge stock compared with private R&D. The public knowledge stock which is produced, however, not only contributes to growth as a direct growth factor, but can also be expected to additionally generate economic value far above the increase in government R&D investment through indirect effects such as the inducement of private R&D.

While the above was a conclusion reached from work on development of a macro-economic model and predictive simulation in this study, this finding must be reconsidered from diverse viewpoints in the process of improvement of the macro-economic model. Main future issues for study are listed below:

(1) The simulation made possible by the presently developed macro-economic model relates to the effects of policy control of total government R&D investment. If it can be applied to simulation of the effects of structural changes in the allocation of funds, not only the total, then the significance of the model as a tool for assisting decision-making in the process of policy making could be substantially improved. For example, in the current model, the exogenous variable of government R&D investment is given by expense, but the possibility that the effects of government R&D investment would differ along with changes in the breakdown of the expenses is not considered. Considering this point, predictive simulation contributing to discussions of the balance among expenses would become possible. In the current model, further, government R&D

Table 5. Trends in Knowledge Stock According to Predictive Simulation

(1) Augmentation Case

(Unit: million yen)

Fiscal year	Private knowledge stock	Public knowledge stock	Imported knowledge stock	Total
2000	86196560	17336750	3635788	107169098
2001	89024790	18115060	3676275	110816125
2002	92784820	18734530	3710463	115229813
2003	97085400	19600020	3738918	120424338
2004	101691700	20294180	3761902	125747782
2005	106527800	21124110	3779726	131431636
2006	111598900	22100710	3792452	137492062
2007	116970800	23240640	3800101	144011541
2008	122658000	24563410	3802761	151024171
2009	128681000	25885930	3800623	158367553
2010	135077800	27216440	3793904	166088144

(2) Trend Case

(Unit: million yen)

Fiscal year	Private knowledge stock	Public knowledge stock	Imported knowledge stock	Total
2000	86196560	17336750	3635788	107169098
2001	89024790	18115060	3676275	110816125
2002	92784820	18734530	3710463	115229813
2003	97085400	19600020	3738918	120424338
2004	101691700	20294180	3761902	125747782
2005	106527800	20998110	3779726	131305636
2006	111598900	21713710	3792485	137105095
2007	116970800	22446030	3800255	143217085
2008	122658000	23200010	3803193	149661203
2009	128665900	23981400	3801563	156448863
2010	135013400	24793670	3795613	163602683

Table 6. Trends in Real GNP According to Predictive Simulation

(Unit: billion yen)

Fiscal year	Augmentation case (a)	Trend case (b)	(a)-(b)
2000	563049	563049	0
2001	575604	575604	0
2002	590481	590481	0
2003	608028	608028	0
2004	626124	626124	0
2005	645431	645034	397
2006	66178	664925	1253
2007	688496	685898	2598
2008	712046	707590	4456
2009	736623	730369	6254
2010	761709	753709	8000

is treated as one sector. If this can be divided by field, then predictive simulation relating to changes in the distribution of funds by field would become possible.

(2) Among the R&D related measures leading to the expansion of the knowledge stock, there are measures for promoting R&D investment in the private sector through tax incentives etc. in addition to R&D investment by the government itself. Further, R&D funds paid for by the government are sometimes used in some private sectors through commissions etc. in addition to being used in national research institutes, national universities, etc. Further, subsidies etc. are used to assist private sector R&D as well. Incorporating this variety of R&D related measures as variables in the model so as to enable predictive simulation contributing to a more effective selection of the policy mix will be an important area for study in the future.

(3) To not only conduct a predictive simulation relating to the effect of a given numerical target, but to also deal with the problem of what level to set the numerical target of government R&D investment, it is necessary to modify the model so as to enable evaluation of the effect of changes in budget allocations to public investment other than government R&D.

(4) The data on the time lag of R&D and the rate of obsolescence of knowledge cited fixed values from findings of existing surveys. These values, however, may not have remained fixed throughout the period of observation and may have changed. For example, if R&D investment accelerates, in general the time lag shortens and the rate of obsolescence tends to increase. The behavior of the factors governing the amount of knowledge stock in this way desirably should be understood from empirical data and the time lag and rate of obsolescence incorporated as endogenous variables.

(5) In research up to now, including the previous studies, the unspoken premise in dealing with the variable of knowledge stock was that all knowledge is used. In the same way as not all capital stock is operated in production activities, there may be portions of the knowledge stock which are actually put to use and portions which are held as latent resources. Therefore, if the concept of the operating rate can be introduced into the variable of knowledge stock, factors influencing the operating rate of knowledge can be found, and those factors built into the model, it would be possible to assess the effects of policy from diverse angles. How to measure the operating rate of knowledge is in itself a difficult matter for study, but it should be possible to obtain a grasp of an index representative of the operating rate by referring to data on surveys relating to the state of unused patents owned by companies and data on patents, papers, and other citations.

(6) The currently developed model considered as the effect which R&D conducted overseas has on the Japanese economy only the effect of knowledge stock introduced through technology imports. Knowledge stock of a nature of a public asset formed by basic foreign scientific research however flows into Japan through the technology market and can have an effect on economic growth. Conversely, public asset type knowledge stock formed by R&D in Japan spreads overseas not depending on technology exports and can be beneficial to the economies where it flows. If the effect of external economies through the spillover of such public asset type technology among countries could be grasped quantitatively and incorporated into a model, it would be possible to forecast the global economic effects of government R&D investment.

(7) One of the issues remaining relating to the general part of a macro-economic model is the improvement to a more precise model since in this model the employment and distribution block in particular used an extremely simple structure.

Finally, a point which should be stressed in future research is that the final target of this research is not to make a more precise predictive simulation. The process of repeated study of the model, in which considerable room remains for improvement, so as to clarify the complicated cause and effect relationship between R&D and economic growth itself would contribute to the development of techniques for prior evaluation of government R&D investment. Further, continuation of the work for improvement of this model taking into consideration policy issues itself would have significance for the macro-economic model as a tool for testing out thinking in the policy-making process. Getting the tool in this sense used in common by policy makers is the main goal of this study.

[Notes]

1. The prototype of the model reported here was completed in the fall of 1995 and presented by Nagata (1995). The prototype was comprised of a total of 26 simultaneous equations and included 35 variables (including 26 endogenous variables and nine exogenous variables). For estimation of the parameters, data from the late 1960s to 1991 was used. Later, however, starting in 1992, the Japanese economy entered a period of business recession. Further, data on the system of national accounts was revised to a 1990 standard. This made major revision in the model necessary and led to the development of the model reported here. The current model differs from the prototype in the period of estimation of the data and the benchmark year and also structural changes such as the expansion of the employment and distribution block and the price block. Note that in April 1996, at the request of the Office for Promotion of the Drafting of the Science and Technology Basic Plan established in the Science and Technology Agency, the prototype was used to make a trial predictive simulation of the economic effect of doubling government R&D investment. The difference between the findings of the prediction announced at that time and the findings of the prediction of this report were mainly due to the above differences in the model and the data used.

2. For details on the method of measurement of the technology knowledge stock, see Goto (1993).

3. For the rate of obsolescence, the average value of the total of industries of the survey was used for the private knowledge stock and imported knowledge stock and the average value of the total for universities and research institutes was used for the public knowledge stock. The survey investigated the time lag dividing it into "production linked techno stock" and "science accumulating techno stock". The time lag for private knowledge stock was found to be four years by taking the weighted average of the "production linked" lag of the total of industries and the "science accumulating" lag of the total of universities and research institutes by the share of private R&D investment by institutions. For the time lag of public knowledge stock, the "science accumulating type" lag of the total of universities and research institutes was referred to.

4. For this type of estimation of production functions, since capital and labor for R&D embodied in the technological knowledge stock are already included in the data on the capital stock and number of employees, the problem of double calculation has been pointed out. Here, however, no processing was done to avoid such double calculation since estimation of the capital stock for just R&D is difficult. See Suzuki and Miyakawa (1986) on this point.

5. In the partial test, the calculated values were found by substituting actual values for all independent variables and using them for comparison with actual values. In the total test, the exogenous variables and predetermined endogenous variables (endogenous variables with lag) of the independent variables were substituted by actual values and the endogenous variables of the period were substituted by calculated values. In the final test, all independent variables except the initial values of the exogenous variables and predetermined endogenous variables were substituted by calculated values.

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Materials

(1) List of Variables

[National Economic Calculations]

GNP	Real gross national product	1 billion yen (1990=100)	Economic Planning Agency, Annual Report on National Accounts
CP	Real private final consumption expenditure	1 billion yen (1990=100)	Economic Planning Agency, Annual Report on National Accounts
CG	Real government final consumption expenditure	1 billion yen (1990=100)	Economic Planning Agency, Annual Report on National Accounts
IH	Real private housing investment	1 billion yen (1990=100)	Economic Planning Agency, Annual Report on National Accounts
IP	Real private enterprise plant and equipment investment	1 billion yen (1990=100)	Economic Planning Agency, Annual Report on National Accounts
IG	Real public fixed capital formation	1 billion yen (1990=100)	Economic Planning Agency, Annual Report on National Accounts
JP	Real private enterprise inventory investment	1 billion yen (1990=100)	Economic Planning Agency, Annual Report on National Accounts
JG	Real public enterprise inventory investment	1 billion yen (1990=100)	Economic Planning Agency, Annual Report on National Accounts
EX	Real exports and income from abroad	1 billion yen (1990=100)	Economic Planning Agency, Annual Report on National Accounts
M	Real imports and income to abroad	1 billion yen (1990=100)	Economic Planning Agency, Annual Report on National Accounts
GNP.N	Nominal gross national product	1 billion yen	Economic Planning Agency, Annual Report on National Accounts
W	Nominal per capita compensation of employees	1000 yen	Economic Planning Agency, Annual Report on National Accounts
PTGNP	Potential gross national product	1 billion yen (1990=100)	Estimate according to present model

[Deflators]

P	Gross national product deflator	1990=100	Economic Planning Agency, Annual Report on National Accounts
PC	Private final consumption expenditure deflator	1990=100	Economic Planning Agency, Annual Report on National Accounts
WPI	Wholesale price index	1990=100	Bank of Japan, Annual Report on Price Index
PRD	R&D expense deflator	1990=100	Materials of Statistical Bureau, Management and Coordination Agency

[Capital Stock]

KP	Real private enterprise plant and equipment capital stock	1 billion yen (1990=100)	Toyo Keizai Shimposha
ROMA	Operating rate index (manufacturing industry)	1990=100	Ministry of International Trade and Industry, Annual Report on Manufacturing Index

[Labor]

L	Number of employed persons	10,000	Management and Coordination Agency, Annual Report on the Labor Force Survey
NL	Labor force population	10,000	Management and Coordination Agency, Annual Report on the Labor Force Survey
LW	Number of employees	10,000	Management and Coordination Agency, Annual Report on the Labor Force Survey

[Financial]

INTN	National bank loan contractual average interest rate	% annual rate	Bank of Japan, Economic Statistics Yearly
INTORA	Official money rate	% annual rate	Bank of Japan, Economic Statistics Yearly

[R&D]

PRRDL	Real private R&D personnel expenses	1 million yen (1990=100)	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PRRDM	Real private R&D material expenses	1 million yen (1990=100)	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PRRDC	Real private R&D plant and equipment investment	1 million yen (1990=100)	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PRRDT	Total real private R&D expenses	1 million yen (1990=100)	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PRP	No. of researchers in private sector	Persons	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PURDL.N	Nominal public R&D personnel expenses	1 million yen	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PURDM.N	Nominal public R&D material expenses	1 million yen	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PURDC.N	Nominal public R&D plant and equipment investment	1 million yen	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PURDL	Real public R&D personnel expenses	1 million yen (1990=100)	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PURDM	Real public R&D material expenses	1 million yen (1990=100)	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PURDC	Real public R&D plant and equipment investment	1 million yen (1990=100)	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PURDT	Total real public R&D expenses	1 million yen (1990=100)	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
PUP	No. of researchers in public sector	Persons	Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values

Notes:

1. Material expenses include "other expenses".
2. Includes data of humanities and social sciences.
3. Private sector includes "companies", "private research institutes", and "private universities". Public sector includes "central government-owned research institutes", "local government-owned research institutes", "government-affiliated agencies and research institutes", "national universities", and

"public universities".

[Technology Imports]

TECHIM.N	Nominal technology imports	1 million yen	General Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values
TECHIM	Real technology imports	1 million yen (1990=100)	General Management and Coordination Agency, Report on the Survey of Research and Development, Processed Values

[Knowledge Stock]

KST	Real knowledge stock total	1 million yen (1990=100)	Estimate by present model
PRKST	Real private knowledge stock	1 million yen (1990=100)	Estimate by present model
PUKST	Real public knowledge stock	1 million yen (1990=100)	Estimate by present model
IMKST	Real imported knowledge stock	1 million yen (1990=100)	Estimate by present model

[Others]

EXR	Exchange rate (Tokyo) yen	Yen/US$	Toyo Keizai Shimposha
DUM8687	Dummy	1986, 1987=1	
DUM8890	Dummy	1988 to 1990=1	

(2) Simultaneous Equation System

[Production Block]

(Production Function)

LOG(GNP)=-1.398+0.301041 LOG(KP*ROMA)+0.698959 LOG(L)+0.164190 LOG(KST)

(-5.87)(8.70) (20.21) (5.55)

(1973-1994)

R^2=0.9981 DW=1.376

Potential GNP

PTGNP=EXP(-1.398+0.301041 LOG(KP*100)+0.698959 LOG(L)+0.164190 LOG(KST))

Private enterprise plant and equipment capital stock

KP-IP=2276.46+0.889071 KP(1)

(2.10) (279.84)

(1974-1994)

R^2=0.9997

KP=2276.46+0.889071 KP(1)+IP

Demand-supply gap

DSGAP=PTGNP/GNP

[Expenditure Block]

Real gross national product

GNP=CP+CG+IH+IP+IG+JP+JG+EX-M

Nominal gross national product

GNP.N=GNP*P/100

Real private final consumption expenditure (consumption function)

CP=7025.43+32.6200 DEL(W)+0.988854 CP(1)-958.229 DOT(PC)

(1.81) (2.84) (64.61) (-4.09)

(1974-1995)

R^2=0.9977

Real private housing investment

IH=-6506.25+325.0559W/PC-473.6579(INTN-DOT(PC))+0.693564IH(1)+2982.10 DUM8687

(-1.15) (1.49) (-1.85) (3.33) (2.56)

(1975-1995)

R^2=0.8154

Real private enterprise plant and equipment investment (investment function)

IP=-74452.2+0.485197DEL(GNP)+4485.61LOG(PRKST)+0.860771IP(1)+3264.34 DUM8890

(-1.95) (5.38) (1.88) (14.96) (2.06)

(1974-1995)

R^2=0.9917

Real exports and income from abroad

LOG(EX)=-15.2832+0.382447 LOG(EXR)+1.36014 LOG(PRKST+PUKST)

(-8.80) (4.36) (18.35)

(1973-1995)

R^2=0.9866 DW=0.866

Real imports and income to abroad

M=1.8397.8-51.2782 EXR+0.820615 M(1)

(2.82) (-2.80) (9.11)

(1973-1995)

R^2=0.9568

[Employment and Distribution Block]

Number of employed persons

L=187.5354+0.944916 NL

(3.24) (97.99)

(1974-1995)

R^2=0.9978 DW=0.435

Number of employees

LW=-434.8323+29.0549 W/PC+0.826775 LW(1)

(-4.65) (4.49) (17.03)

(1974-1994)

R^2=0.9973

Nominal per capita compensation of employees

W=-1982.98+32.8361 PC+48.6457 PTGNP/L+62.4846 DUM8890

(-32.50) (17.04) (15.65) (2.38)

(1974-1994)

R^2=0.9983 DW=1.384

[Price Block]

Gross national product deflator

P=9.00788+0.906353 PC

(13.17) (115.22)

(1972-1995)

R^2=0.9983 DW=0.909

Private final consumption expenditure deflator

PC=28.6446-0.330384 PTGNP(1)/L(1)+0.157533 WPI+0.017182 W(1)

(4.63) (-2.10) (5.53) (11.43)

(1974-1994)

R^2=0.9977

R&D expense deflator

PRD=-2.66788+0.999793 PC

(-2.45) (79.95)

(1972-1995)

R^2=0.9964 DW=1.034

Wholesale price index

WPI=10.8896+0.027077 EXR+0.843497 WPI(1)

(1.33) (1.69) (12.58)

(1972-1995)

R^2=0.8809

Interest rates (national bank loan contractual average interest rate)

INTN=1.94719+0.573701 INTORA+0.290853 INTN(1)

(8.40) (21.43) (7.04)

(1974-1994)

R^2=0.9825

[R&D Block]

Knowledge stock total

KST=PRKST+PUKST+IMKST

(Private Sector)

Real private R&D personnel expenses

PRRDL=-1969162+15.8162 CP+3.71988 PRP

(-34.51) (13.83) (9.13)

(1973-1995)

R^2=0.9976 DW=1.850

Real private R&D material expenses

PRRDM=-3144554+10.5257 PRP

(-10.26) (20.22)

(1973-1995)

R^2=0.9488 DW=0.4

Real private R&D plant and equipment investment

PRRDC=7066654+31252.9 PRRDC(1)/IP(1)-7623487 DSGAP(1)+0.116075 PUKST

(6.09) (4.38) (-7.06) (15.43)

(1975-1995)

R^2=0.9500

Real private R&D expenses, total

PRRDT=PRRDL+PRRDM+PRRDC

Private knowledge stock

PRKST=0.898*PRKST(1)+PRRDT(4)

Number of private sector researchers

PRP=-78295.0+3671.18 PRP(1)/LW(1)+0.004939 PRKST

(-0.95) (4.70) (7.97)

(1974-1995)

R^2=0.9674

(Public Sector)

Real public R&D personnel expenses
PURDL=PURDL.N/PRD*100

Real public R&D material expenses
PURDM=PURDM.N/PRD*100

Real public R&D plant and equipment investment
PURDC=PURDC.N/PRD*100

Real public R&D expenses, total
PURDT=PURDL+PURDM+PURDC

Public knowledge stock
PUKST=0.897*PUKST(1)+PURDT(8)

Number of public sector researchers
PUP=41458.9+0.026349 PURDL.N+0.670376 PUP(1)
(2.43) (3.90) (5.79)
(1975-1995)
R^2=0.9470
(Technology Imports)

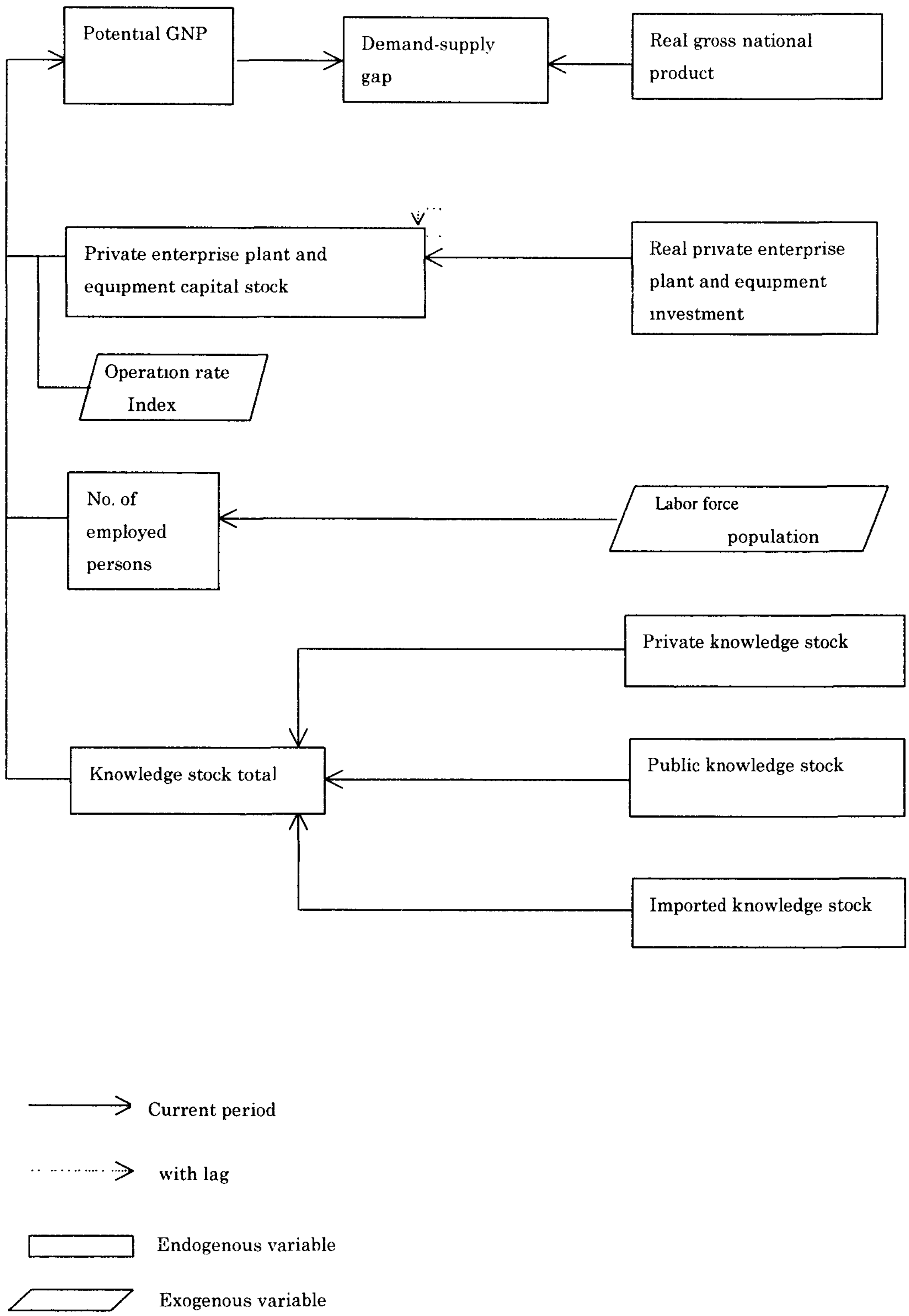
Nominal technology imports
TECHIM.N=33914.9+1.74782 M+0.671533 TECHIM.N(1)
(2.43) (2.96) (6.31)
(1972-1995)
R^2=0.9439

Real technology imports
TECHIM=TECHIM.N/PRD*100

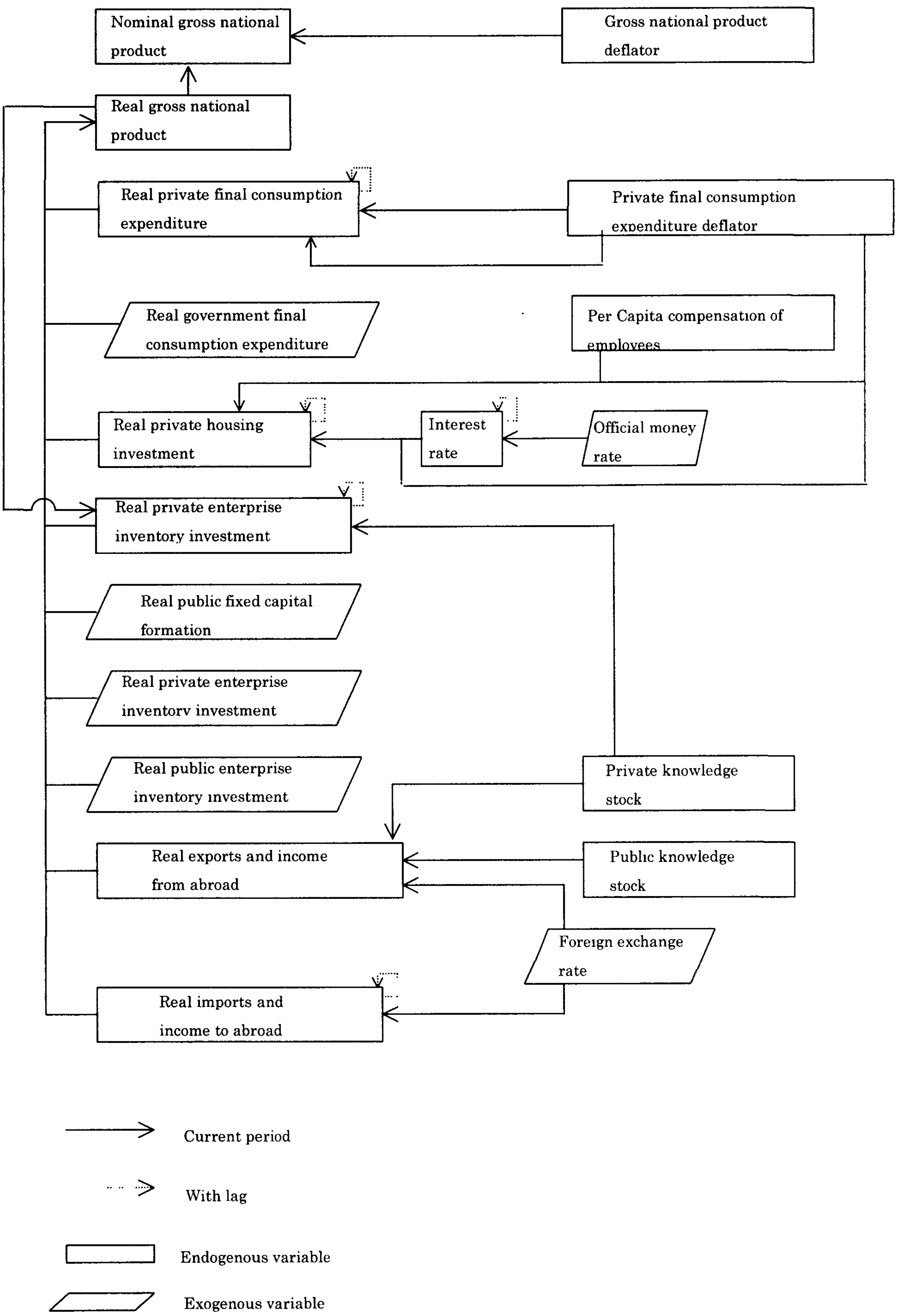
Imported knowledge stock
IMKST=0.898*IMKST(1)+TECHIM

(3) Flow of Model by Blocks

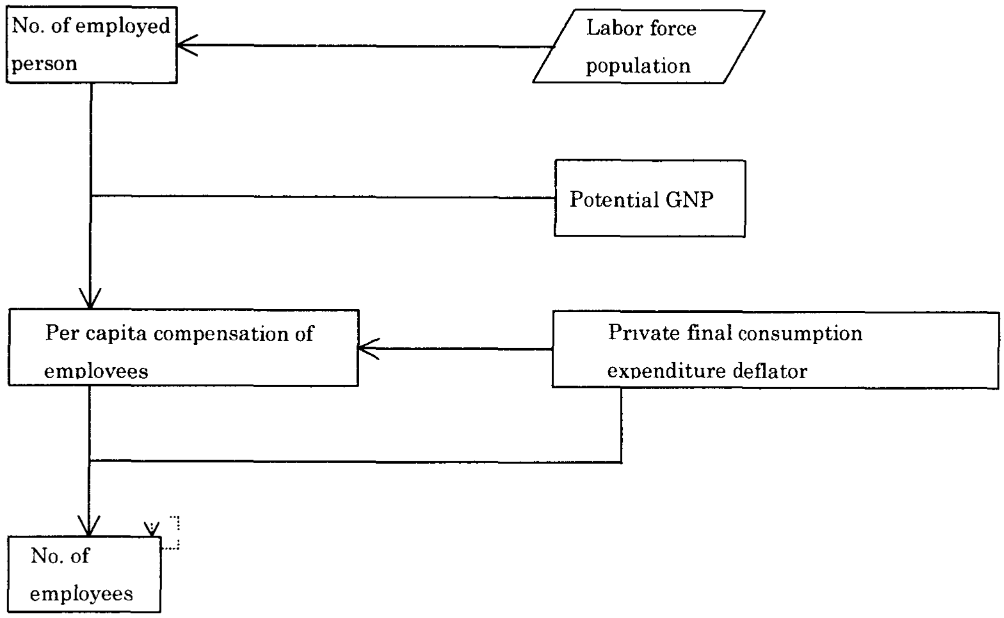
【Production】

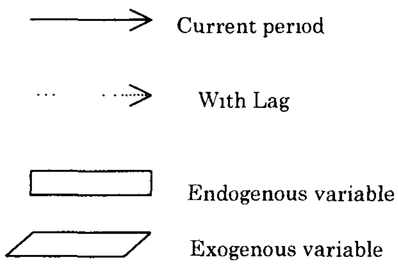


【Expenditure Block】

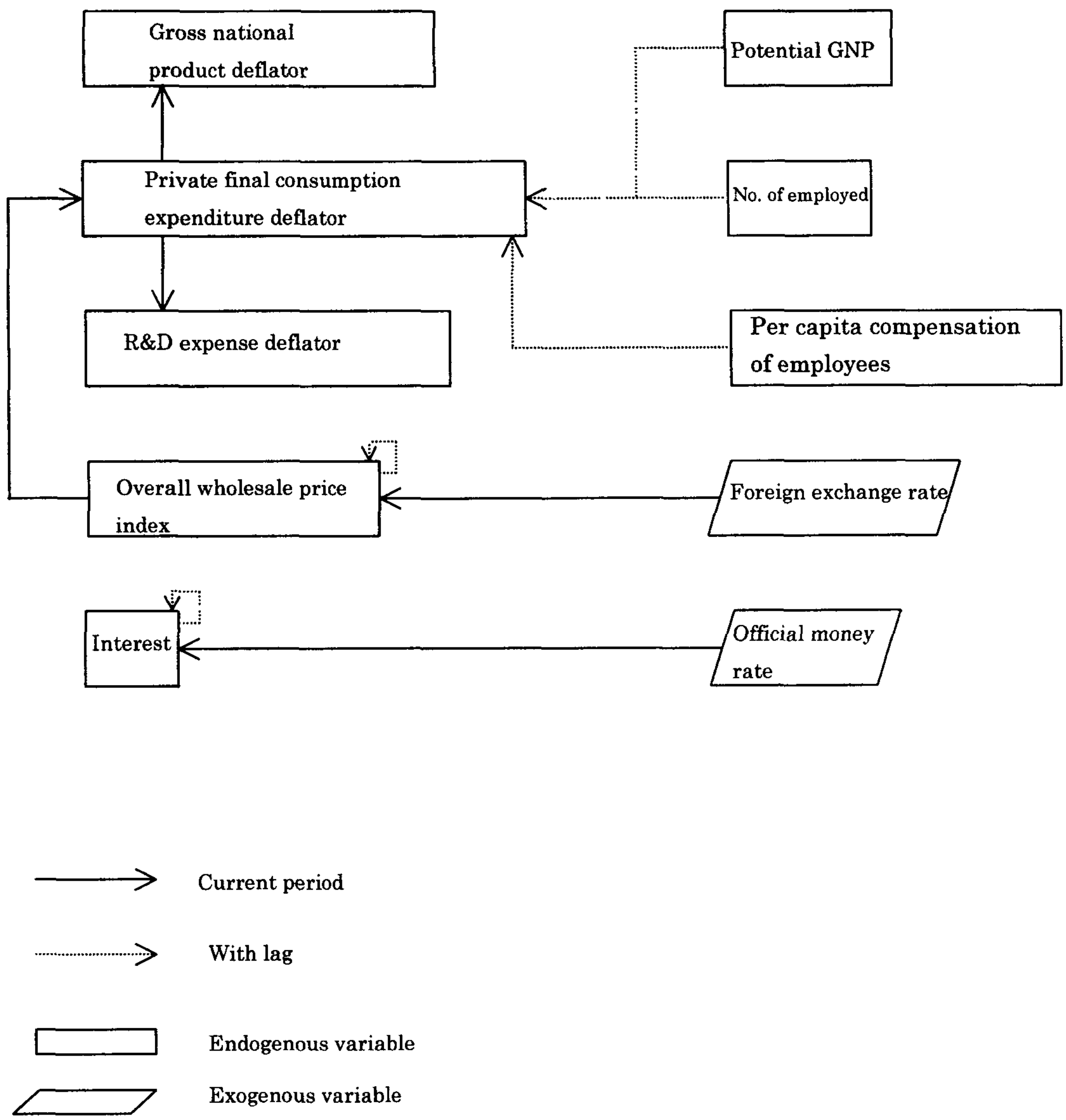


[Employment and Distribution Block]



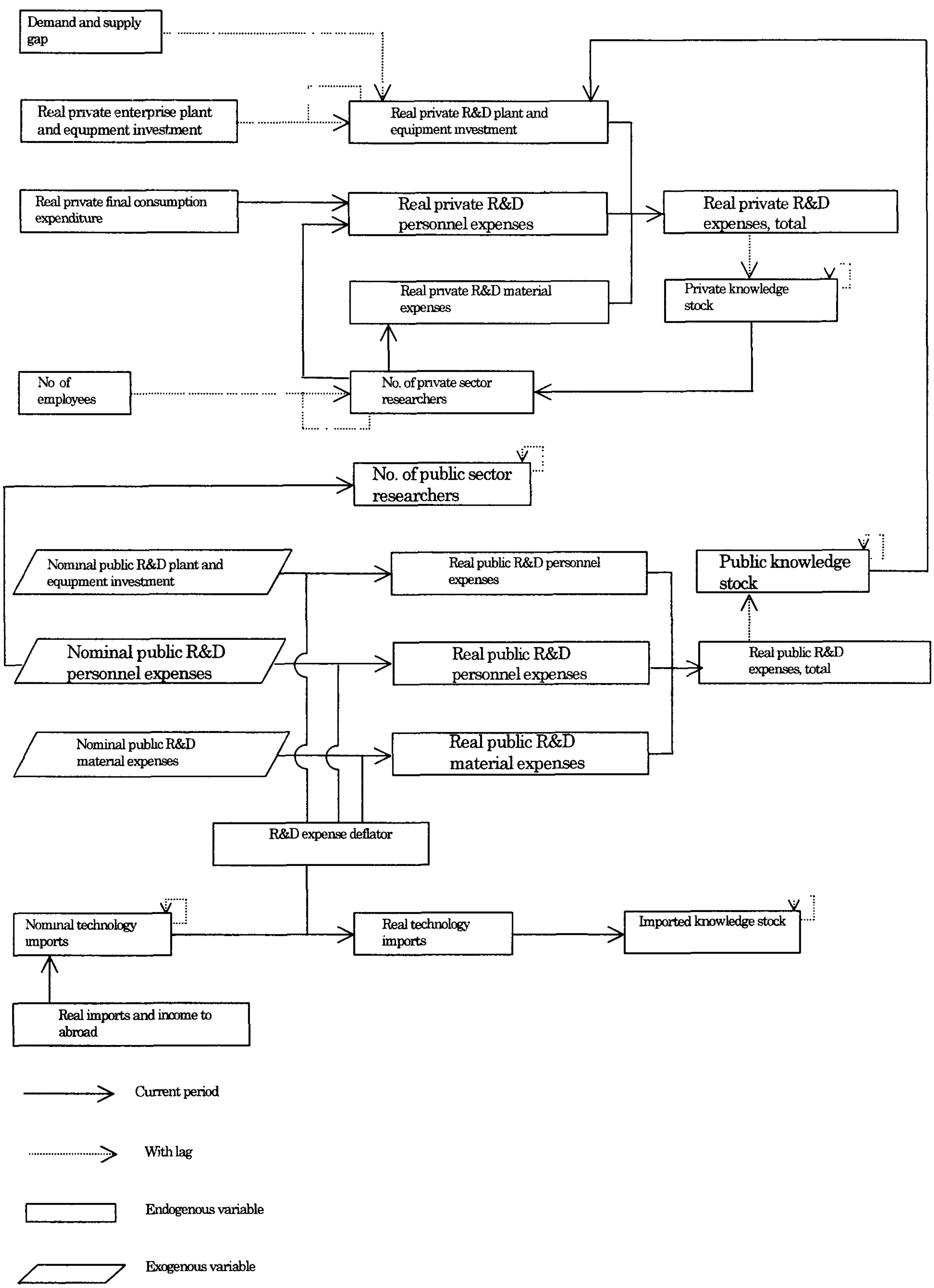


【Price Block】



Gross national product deflator
Potential GNP
Private final consumption expenditure deflator
No. of employed
R&D expense deflator
Per capita compensation of employees
Overall wholesale price index
Foreign exchange rate
Interest
Official money rate
Current period
With lag
Endogenous variable
Exogenous variable

【R&D Block】



Demand and supply gap
Real private enterprise plant and equipment investment
Real private R&D plant and equipment investment
Real private final consumption expenditure
Real private R&D personnel expenses
Real private R&D expenses, total
Real private R&D material expenses
Private knowledge stock
No of employees
No. of private sector researchers
No. of public sector researchers
Nominal public R&D plant and equipment investment
Real public R&D personnel expenses
Public knowledge stock
Nominal public R&D personnel expenses
Real public R&D personnel expenses
Real public R&D expenses, total
Nominal public R&D material expenses
Real public R&D material expenses
R&D expense deflator
Nominal technology imports
Real technology imports
Imported knowledge stock
Real imports and income to abroad
Current period
With lag
Endogenous variable
Exogenous variable

(4) Results of Interpolation Test

(Unit: %)

	Partial test	Total test	Final test
PTGNP	0.00	0.41	1.45
KP	0.38	1.09	3.14
L	0.24	0.24	0.24
KST	0.00	0.03	2.59
IP	2.25	7.26	8.07
DSGAP	0.00	1.67	1.62
GNP	0.00	2.06	1.89
CP	0.79	1.08	1.60
IH	4.60	4.99	4.87
EX	4.38	4.38	4.67
M	6.18	6.18	8.91
GNP.N	0.00	2.32	2.17
P	0.54	0.65	1.05
W	0.64	0.93	1.85
PC	0.61	0.69	1.43
INTN	2.14	2.14	2.39
PRKST	0.00	0.00	3.66
PUKST	0.00	0.00	0.70
LW	0.49	0.53	1.34
WPI	2.93	2.93	4.98
PRD	1.05	1.42	1.90
IMKST	0.00	0.56	1.12
PRRDL	1.47	2.37	4.82
PRP	2.66	2.66	6.51
PRRDM	8.48	11.40	14.37
PRRDC	5.98	5.98	23.34
PRRDT	0.00	5.36	7.98
DURDL	0.00	1.43	1.89
PURDM	0.00	1.39	1.74
PURDC	0.00	1.43	1.94
PURDT	0.00	1.42	1.86
PUP	1.21	1.21	1.39
TECHIM.N	5.18	5.26	6.25
TECHIM	0.00	4.75	4.82

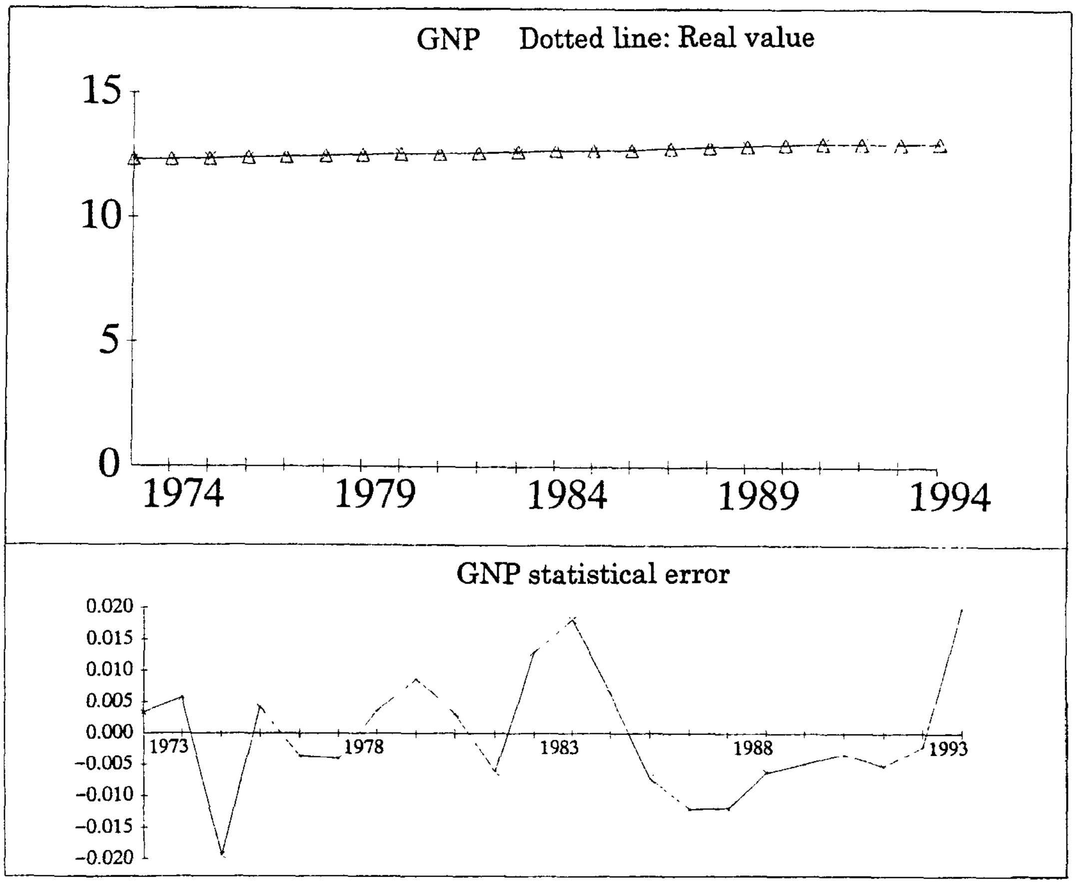
Notes: Figures are average absolute error rates according to following formula:

$$\Sigma|E_t - 0_t| / \Sigma|O_t|$$

where, E: estimated value, O: real value, t = 1 to n, n: test period.

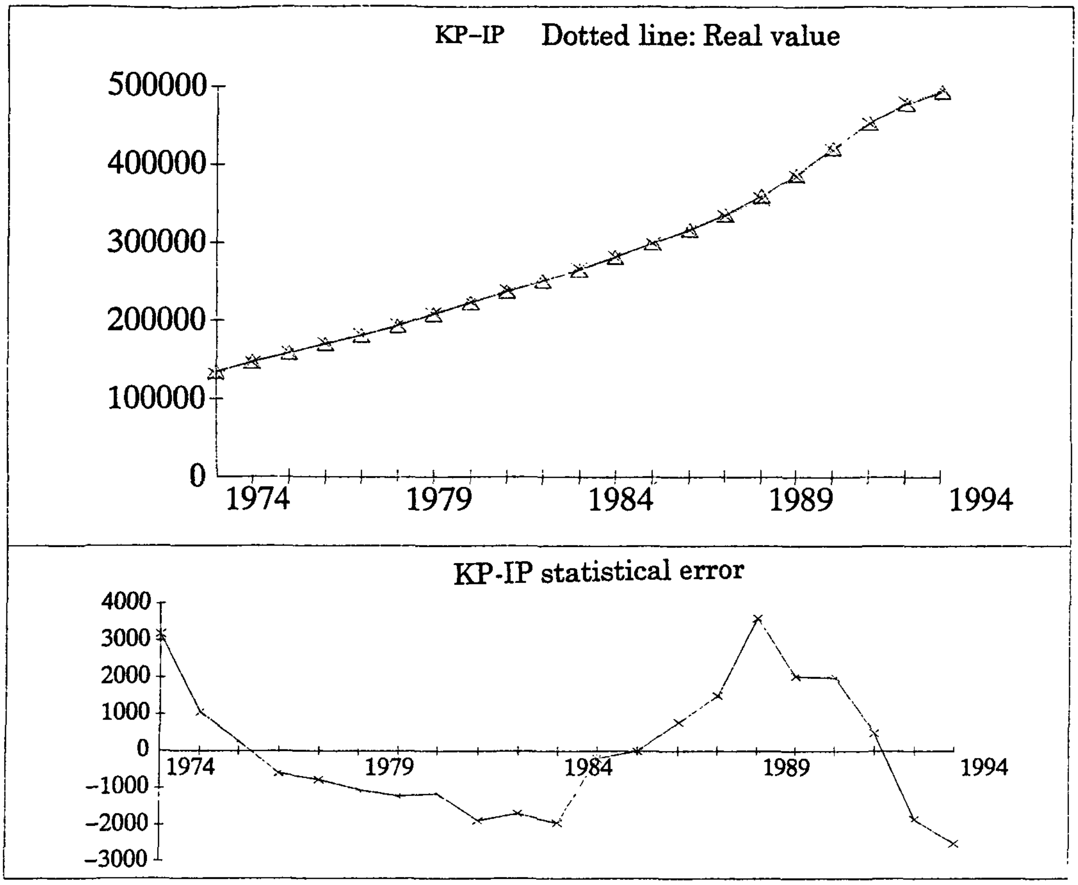
(5) Fitness of Equations

Real gross national product (production function)



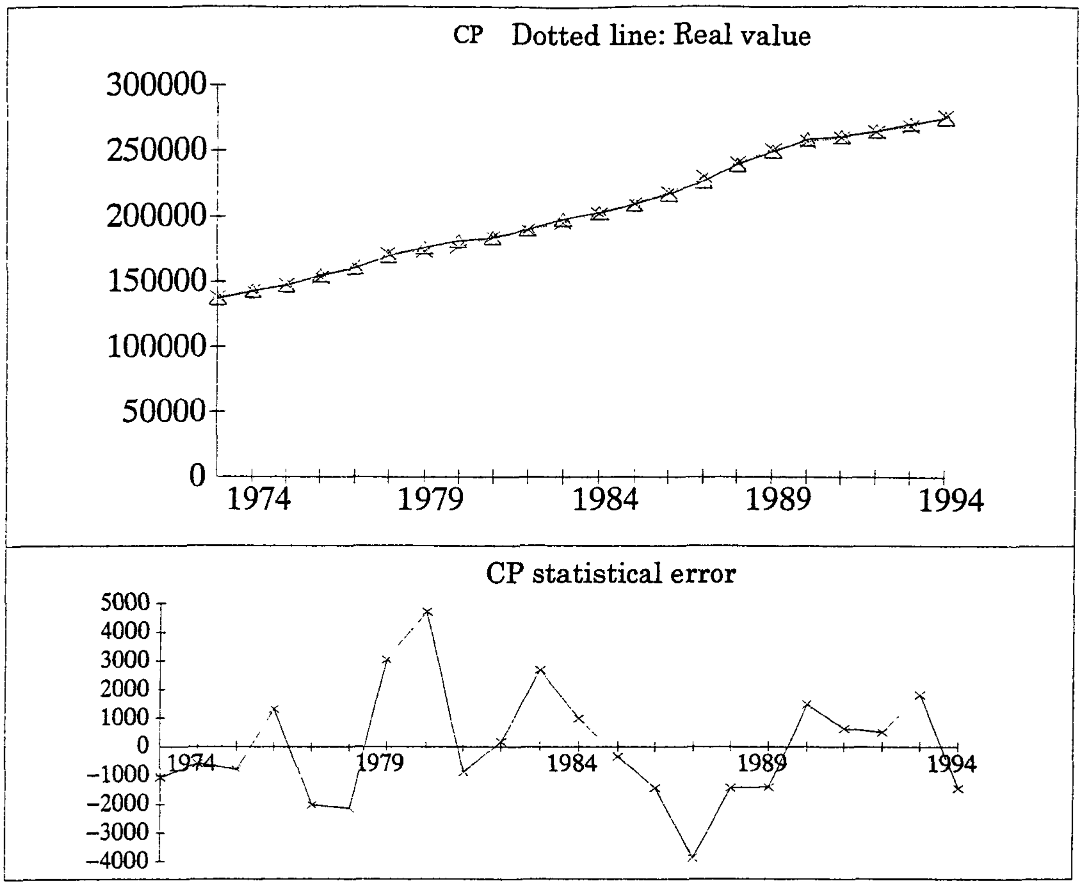
Trend in error	Real value	Estimated value	Error	Error ratio
1973	12.343	12.346	.003	0.0
1974	12.336	12.342	.006	0.0
1975	12.376	12.357	-.019	-0.2
1976	12.413	12.418	.004	0.0
1977	12.458	12.455	-.004	0.0
1978	12.512	12.508	-.004	0.0
1979	12.562	12.566	.004	0.0
1980	12.586	12.595	.009	0.1
1981	12.615	12.618	.003	0.0
1982	12.647	12.641	-.006	0.0
1983	12.673	12.686	.013	0.1
1984	12.714	12.732	.018	0.1
1985	12.756	12.763	.006	0.1
1986	12.787	12.780	-.007	-0.1
1987	12.836	12.824	-.012	-0.1
1988	12.894	12.882	-.012	-0.1
1989	12.940	12.934	-.006	0.0
1990	12.992	12.987	-.005	0.0
1991	13.023	13.020	-.003	0.0
1992	13.030	13.025	-.005	0.0
1993	13.031	13.029	-.002	0.0
1994	13.035	13.055	.020	0.2

Private enterprise plant and equipment capital stock



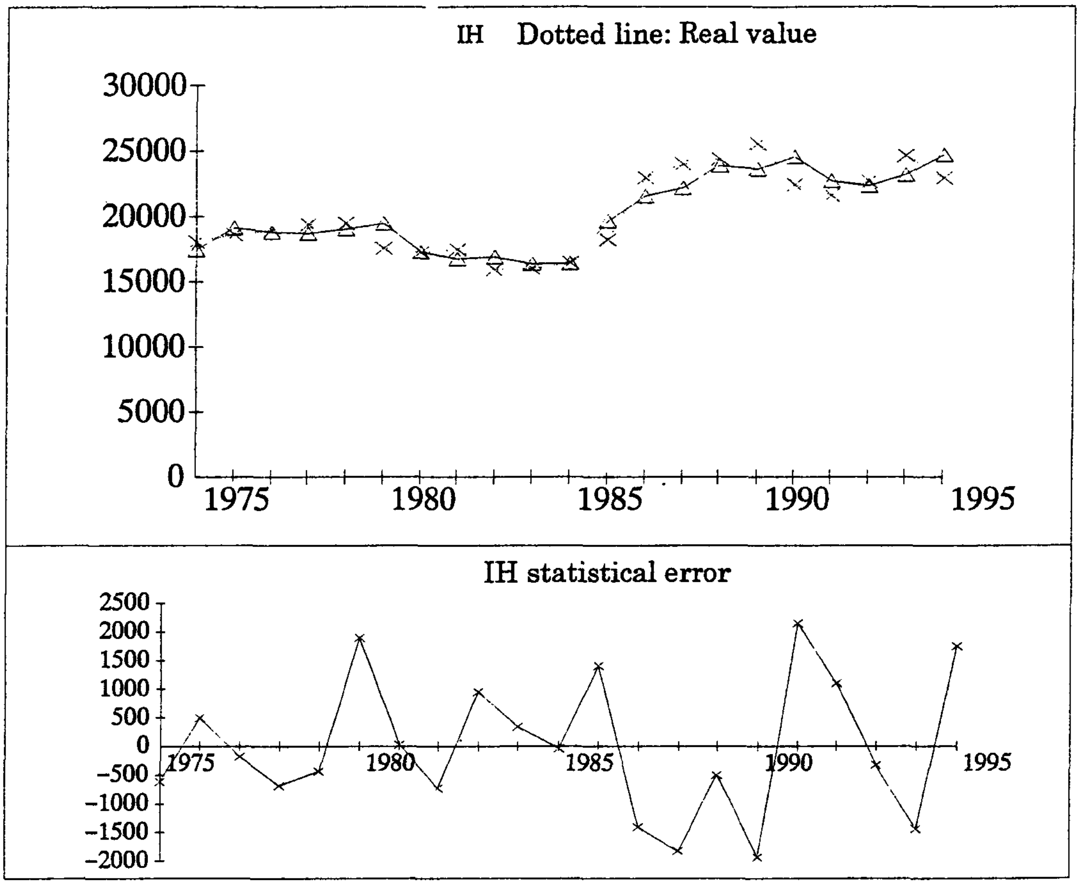
Trend in error	Real value	Estimated value	Error	Error ratio
1974	131, 835. 0	135, 012. 4	3, 177. 4	2. 4
1975	146, 428. 4	147, 476. 2	1, 047. 8	0. 7
1976	159, 127. 9	159, 393. 6	265. 7	0. 2
1977	171, 453. 3	170, 855. 4	-597. 9	-0. 3
1978	182, 386. 4	181, 609. 8	-776. 7	-0. 4
1979	194, 666. 4	193, 627. 4	-1, 039. 0	-0. 5
1980	208, 895. 6	207, 677. 5	-1, 218. 1	-0. 6
1981	223, 907. 0	222, 756. 0	-1, 151. 1	-0. 5
1982	238, 900. 5	237, 009. 5	-1, 891. 0	-0. 8
1983	252, 270. 6	250, 571. 9	-1, 698. 7	-0. 7
1984	265, 997. 3	264, 048. 9	-1, 948. 4	-0. 7
1985	280, 814. 8	280, 610. 6	-204. 1	-0. 1
1986	298, 792. 1	298, 785. 3	-6. 9	0. 0
1987	315, 499. 7	316, 269. 0	769. 3	0. 2
1988	333, 435. 3	334, 939. 4	1, 504. 1	0. 5
1989	355, 889. 3	359, 497. 7	3, 608. 4	1. 0
1990	384, 899. 1	386, 935. 4	2, 036. 4	0. 5
1991	418, 430. 2	420, 421. 4	1, 991. 2	0. 5
1992	451, 817. 7	452, 296. 3	478. 6	0. 1
1993	478, 186. 1	476, 341. 7	-1, 844. 4	-0. 4
1994	494, 683. 0	492, 180. 3	-2, 502. 7	-0. 5

Real private final consumption expenditure (consumption function)



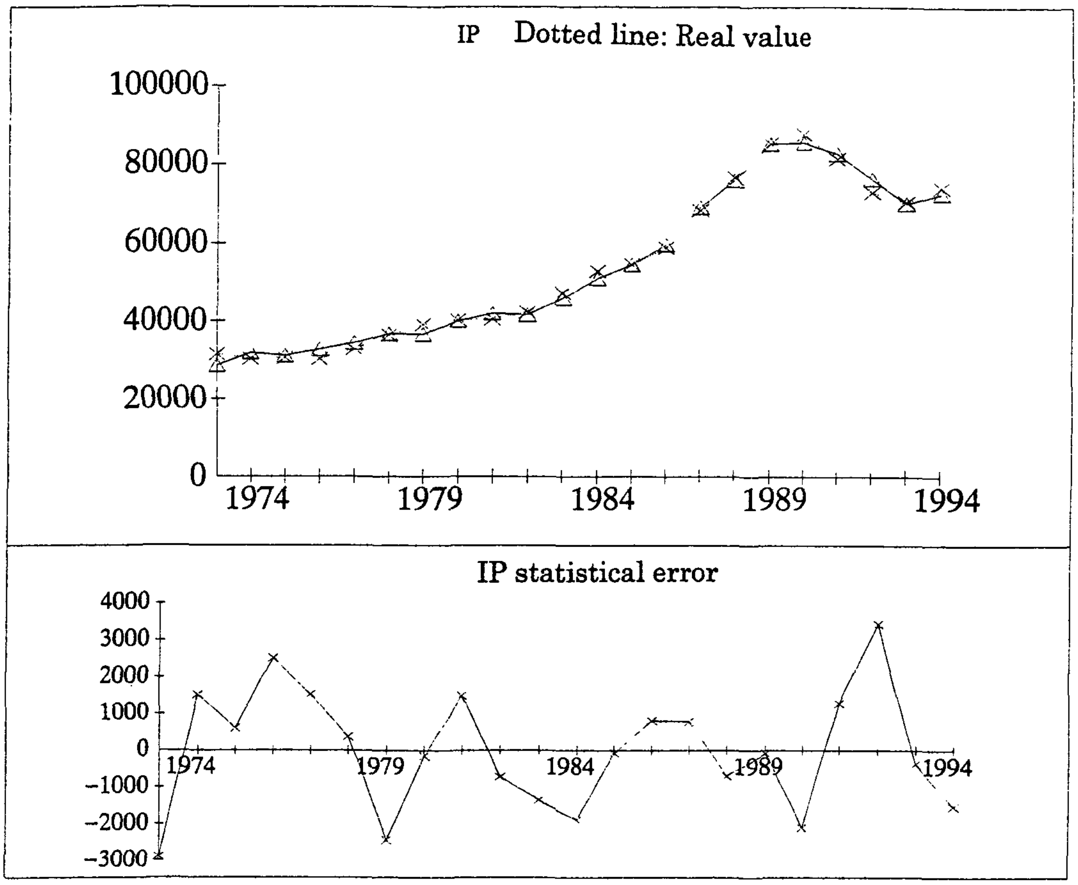
Trend in error	Real value	Estimated value	Error	Error ratio
1974	138, 509. 3	137, 448. 6	−1, 060. 6	−0. 8
1975	143, 400. 4	142, 820. 1	−580. 3	−0. 4
1976	148, 213. 0	147, 414. 2	−798. 8	−0. 5
1977	154, 293. 0	155, 614. 1	1, 321. 1	0. 9
1978	163, 327. 5	161, 306. 4	−2, 021. 1	−1. 2
1979	172, 122. 6	169, 983. 8	−2, 138. 8	−1. 2
1980	173, 354. 2	176, 403. 0	3, 048. 8	1. 8
1981	176, 965. 6	181, 689. 0	4, 723. 4	2. 7
1982	185, 013. 9	184, 141. 8	−872. 1	−0. 5
1983	190, 521. 9	190, 698. 5	176. 6	0. 1
1984	195, 319. 8	198, 007. 2	2, 687. 4	1. 4
1985	202, 226. 3	203, 210. 9	984. 6	0. 5
1986	210, 122. 4	209, 779. 1	−343. 4	−0. 2
1987	218, 771. 5	217, 343. 1	−1, 428. 4	−0. 7
1988	230, 947. 8	227, 069. 0	−3, 878. 8	−1. 7
1989	240, 750. 5	239, 326. 1	−1, 424. 4	−0. 6
1990	250, 755. 8	249, 356. 3	−1, 399. 5	−0. 6
1991	257, 801. 0	259, 282. 2	1, 481. 2	0. 6
1992	260, 812. 3	261, 446. 3	634. 0	0. 2
1993	265, 162. 3	265, 670. 2	508. 0	0. 2
1994	269, 009. 5	270, 832. 1	1, 822. 6	0. 7
1995	276, 264. 7	274, 823. 1	−1, 441. 6	−0. 5

Real Private housing investment



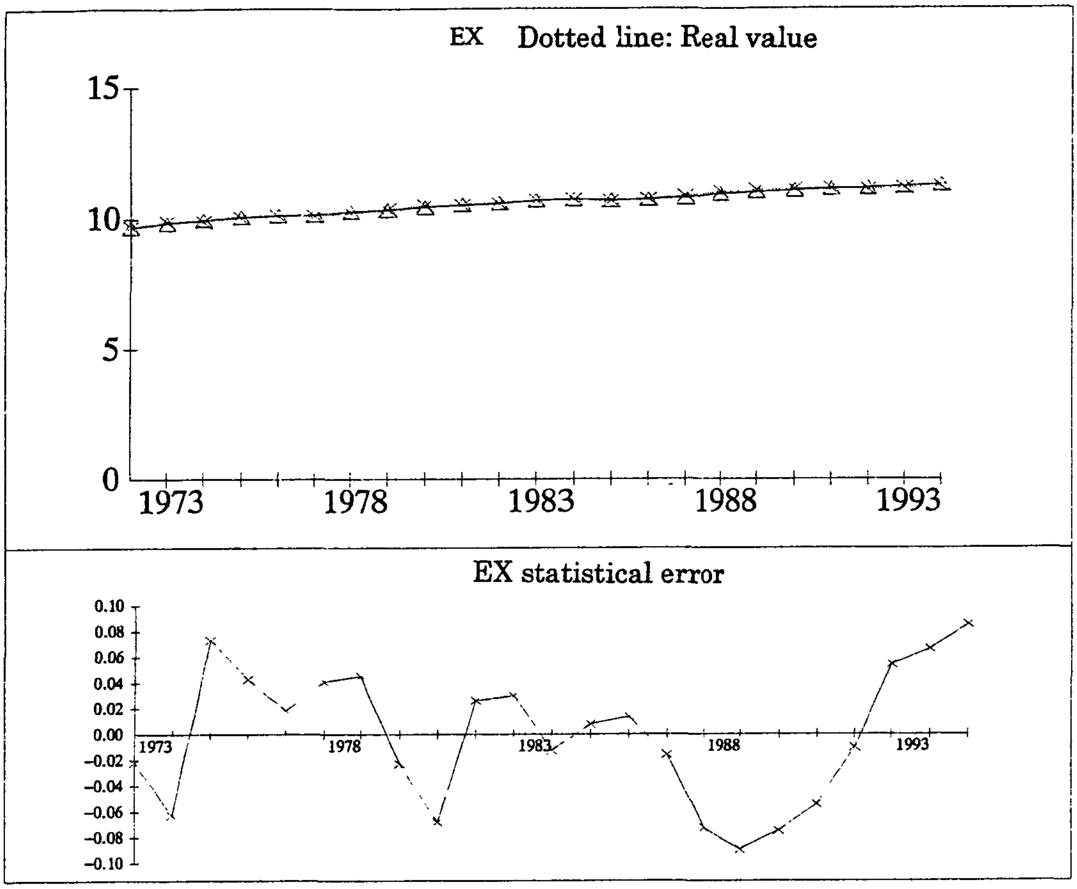
Trend in error	Real value	Estimated value	Error	Error ratio
1975	18, 081. 5	17, 462. 8	-618. 7	-3. 4
1976	18, 669. 6	19, 163. 1	493. 5	2. 6
1977	18, 999. 7	18, 821. 6	-178. 1	-0. 9
1978	19, 430. 3	18, 744. 6	-685. 7	-3. 5
1979	19, 512. 3	19, 077. 0	-435. 3	-2. 2
1980	17, 571. 3	19, 468. 8	1, 897. 5	10. 8
1981	17, 259. 8	17, 287. 4	27. 6	0. 2
1982	17, 471. 4	16, 740. 2	-731. 2	-4. 2
1983	15, 940. 1	16, 891. 7	951. 6	6. 0
1984	16, 014. 4	16, 356. 5	342. 1	2. 1
1985	16, 457. 9	16, 419. 4	-38. 5	-0. 2
1986	18, 226. 2	19, 632. 5	1, 406. 3	7. 7
1987	22, 953. 8	21, 547. 5	-1, 406. 3	-6. 1
1988	24, 002. 0	22, 176. 2	-1, 825. 8	-7. 6
1989	24, 390. 0	23, 887. 8	-502. 2	-2. 1
1990	25, 576. 3	23, 636. 0	-1, 940. 4	-7. 6
1991	22, 434. 8	24, 582. 5	2, 147. 7	9. 6
1992	21, 652. 6	22, 759. 1	1, 106. 5	5. 1
1993	22, 707. 6	22, 380. 0	-327. 6	-1. 4
1994	24, 657. 9	23, 222. 7	-1, 435. 2	-5. 8
1995	22, 996. 7	24, 748. 8	1, 752. 1	7. 6

Real private enterprise plant and equipment investment (investment function)



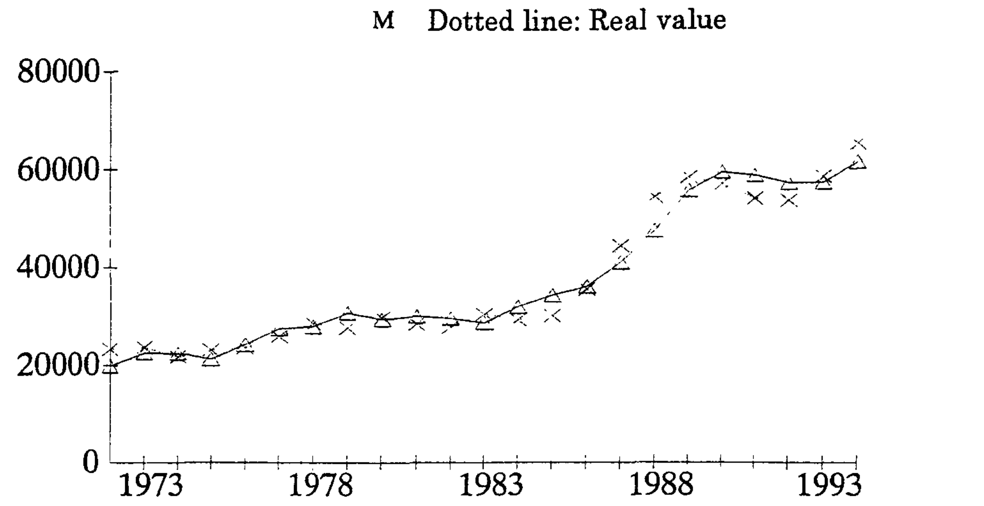
Trend in error	Real value	Estimated value	Error	Error ratio
1974	31, 481. 2	28, 583. 9	−2, 897. 3	−9. 2
1975	30, 292. 2	31, 812. 2	1, 520. 0	5. 0
1976	30, 484. 7	31, 079. 6	594. 9	2. 0
1977	30, 255. 3	32, 774. 6	2, 519. 2	8. 3
1978	32, 839. 4	34, 364. 2	1, 524. 8	4. 6
1979	36, 362. 5	36, 732. 4	369. 9	1. 0
1980	39, 093. 1	36, 651. 6	−2, 441. 5	−6. 2
1981	40, 113. 6	39, 958. 0	−155. 6	−0. 4
1982	40, 374. 8	41, 867. 1	1, 492. 4	3. 7
1983	42, 163. 1	41, 442. 1	−721. 0	−1. 7
1984	47, 064. 6	45, 722. 9	−1, 341. 8	−2. 9
1985	52, 689. 4	50, 793. 3	−1, 896. 1	−3. 6
1986	54, 377. 2	54, 295. 2	−82. 0	−0. 2
1987	58, 669. 5	59, 471. 3	801. 8	1. 4
1988	68, 356. 4	69, 134. 9	778. 5	1. 1
1989	76, 763. 6	76, 065. 8	−697. 8	−0. 9
1990	85, 417. 8	85, 337. 1	−80. 7	−0. 1
1991	87, 738. 5	85, 637. 7	−2, 100. 9	−2. 4
1992	81, 396. 6	82, 667. 8	1, 271. 1	1. 6
1993	72, 842. 9	76, 280. 1	3, 437. 2	4. 7
1994	70, 310. 8	69, 937. 8	−373. 0	−0. 5
1995	73, 901. 9	72, 379. 6	−1, 522. 3	−2. 1

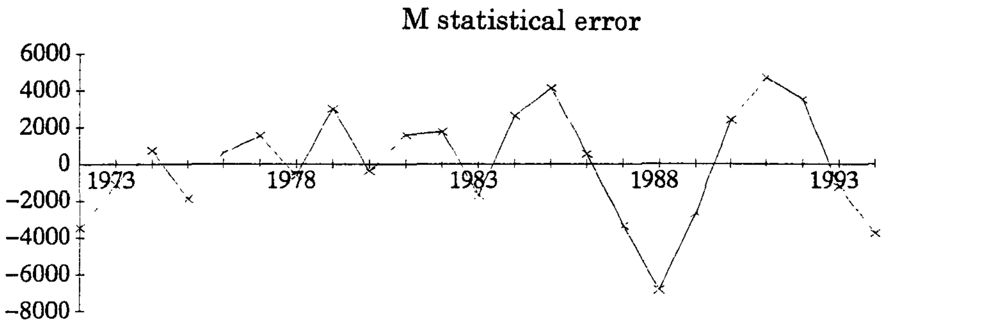
Real exports and income from abroad



Trend in error	Real value	Estimated value	Error	Error ratio
1973	9.705	9.684	-.022	-0.2
1974	9.902	9.840	-.062	-0.6
1975	9.896	9.969	.073	0.7
1976	10.035	10.078	.043	0.4
1977	10.117	10.135	.018	0.2
1978	10.098	10.139	.041	0.4
1979	10.231	10.277	.045	0.4
1980	10.361	10.339	-.023	-0.2
1981	10.503	10.435	-.068	-0.6
1982	10.515	10.541	.026	0.3
1983	10.564	10.594	.030	0.3
1984	10.694	10.682	-.013	-0.1
1985	10.721	10.729	.008	0.1
1986	10.677	10.691	.014	0.1
1987	10.742	10.726	-.016	-0.1
1988	10.859	10.787	-.072	-0.7
1989	11.015	10.925	-.089	-0.8
1990	11.088	11.014	-.075	-0.7
1991	11.133	11.079	-.054	-0.5
1992	11.151	11.141	-.010	-0.1
1993	11.120	11.174	.054	0.5
1994	11.168	11.234	.066	0.6
1995	11.223	11.308	.085	0.8

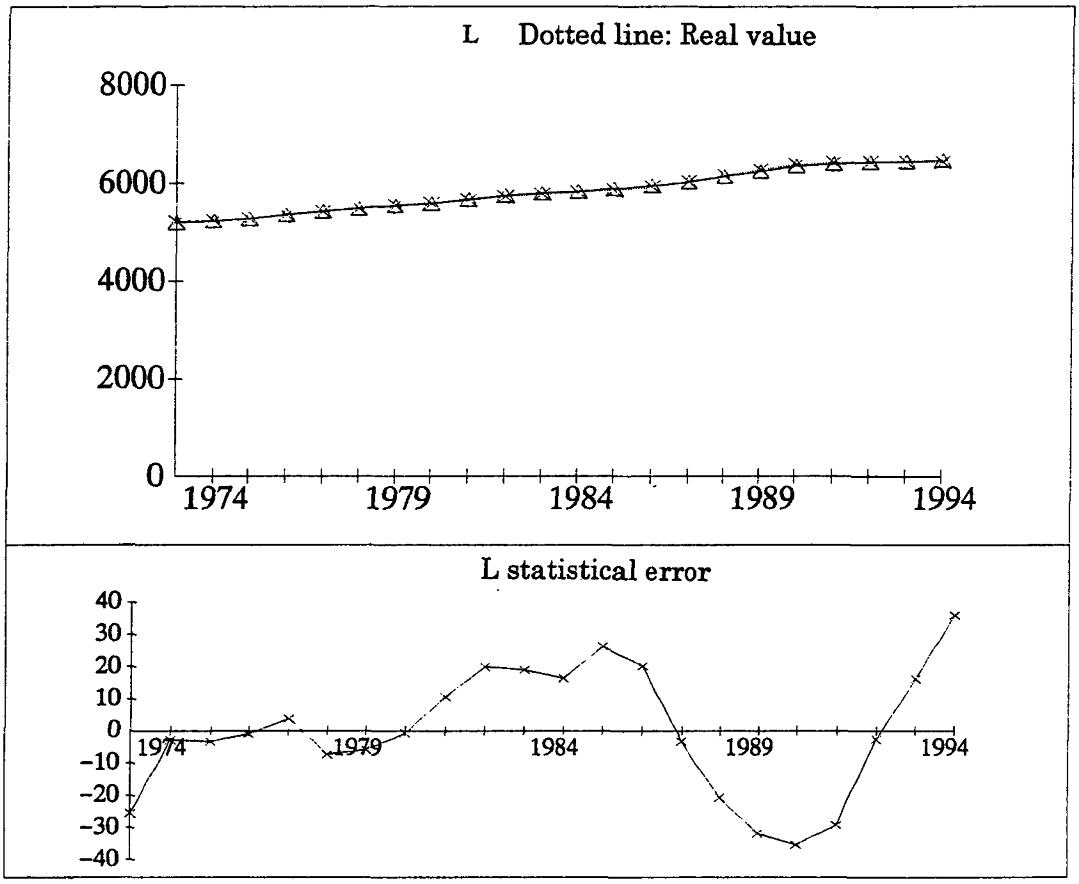
Real imports and income to abroad





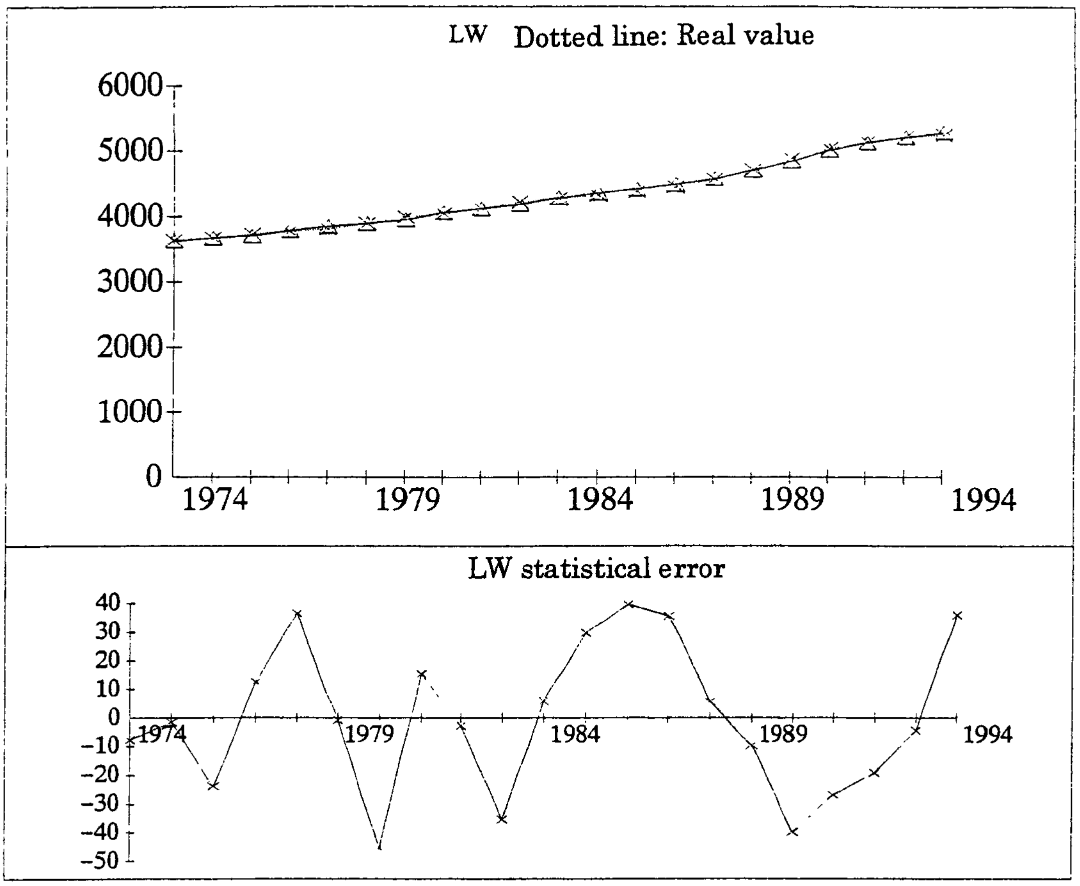
Trend in error	Real value	Estimated value	Error	Error ratio
1973	23, 322. 7	19, 860. 1	-3, 462. 6	-14. 8
1974	23, 641. 8	22, 527. 6	-1, 114. 1	-4. 7
1975	21, 719. 5	22, 463. 4	743. 9	3. 4
1976	23, 115. 1	21, 230. 0	-1, 885. 1	-8. 2
1977	23, 608. 1	24, 212. 0	603. 9	2. 6
1978	25, 919. 3	27, 443. 5	1, 524. 2	5. 9
1979	28, 526. 8	27, 891. 1	-635. 7	-2. 2
1980	27, 651. 8	30, 667. 2	3, 015. 3	10. 9
1981	29, 757. 3	29, 380. 5	-376. 9	-1. 3
1982	28, 405. 7	30, 014. 0	1, 608. 4	5. 7
1983	27, 834. 1	29, 585. 3	1, 751. 2	6. 3
1984	30, 432. 8	28, 730. 6	-1, 702. 2	-5. 6
1985	29, 377. 2	32, 004. 1	2, 626. 9	8. 9
1986	30, 181. 6	34, 306. 8	4, 125. 2	13. 7
1987	35, 525. 8	36, 065. 8	540. 1	1. 5
1988	44, 347. 3	40, 973. 3	-3, 373. 9	-7. 6
1989	54, 318. 9	47, 466. 3	-6, 852. 6	-12. 6
1990	58, 403. 6	55, 715. 9	-2, 687. 8	-4. 6
1991	57, 092. 9	59, 488. 8	2, 396. 0	4. 2
1992	54, 171. 0	58, 853. 2	4, 682. 2	8. 6
1993	53, 818. 2	57, 324. 1	3, 505. 8	6. 5
1994	58, 715. 3	57, 468. 4	-1, 246. 9	-2. 1
1995	65, 428. 3	61, 642. 9	-3, 785. 4	-5. 8

Number of employed persons



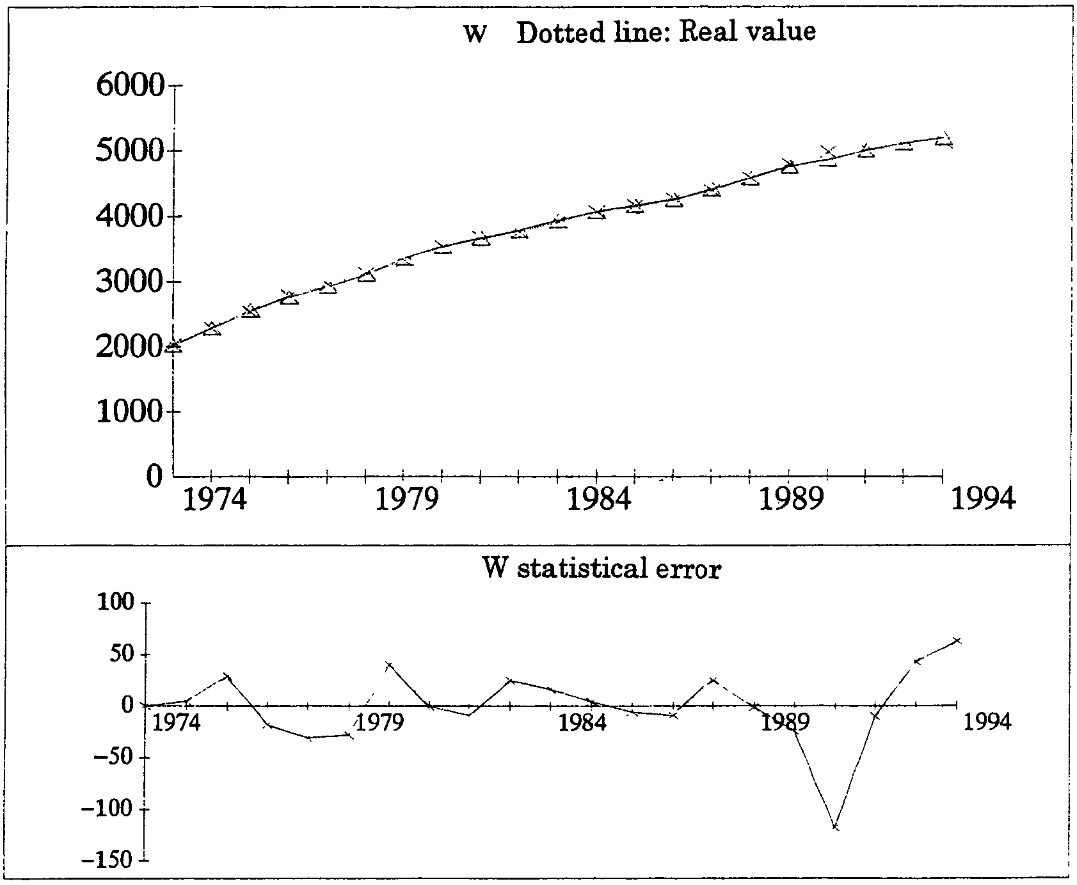
Trend in error	Real value	Estimated value	Error	Error ratio
1974	5, 223. 00	5, 197. 48	-25. 52	-0. 5
1975	5, 240. 00	5, 237. 17	-2. 83	-0. 1
1976	5, 282. 00	5, 278. 74	-3. 26	-0. 1
1977	5, 358. 00	5, 357. 17	-. 83	0. 0
1978	5, 427. 00	5, 430. 87	3. 87	0. 1
1979	5, 493. 00	5, 485. 68	-7. 32	-0. 1
1980	5, 552. 00	5, 546. 15	-5. 85	-0. 1
1981	5, 594. 00	5, 593. 40	-. 60	0. 0
1982	5, 664. 00	5, 674. 66	10. 66	0. 2
1983	5, 735. 00	5, 754. 98	19. 98	0. 3
1984	5, 786. 00	5, 805. 06	19. 06	0. 3
1985	5, 817. 00	5, 833. 41	16. 41	0. 3
1986	5, 860. 00	5, 886. 32	26. 32	0. 4
1987	5, 936. 00	5, 956. 25	20. 25	0. 3
1988	6, 036. 00	6, 032. 78	-3. 22	-0. 1
1989	6, 163. 00	6, 142. 39	-20. 61	-0. 3
1990	6, 280. 00	6, 248. 23	-31. 77	-0. 5
1991	6, 395. 00	6, 359. 73	-35. 27	-0. 6
1992	6, 437. 00	6, 407. 92	-29. 08	-0. 5
1993	6, 454. 00	6, 451. 38	-2. 62	0. 0
1994	6, 455. 00	6, 471. 23	16. 23	0. 3
1995	6, 456. 00	6, 492. 01	36. 01	0. 6

Number of employees



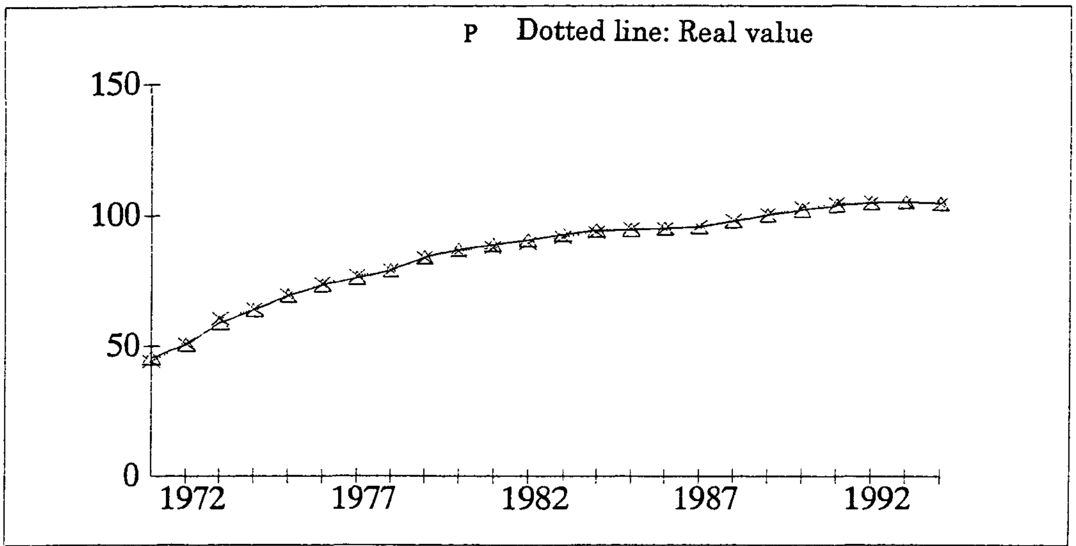
Trend in error	Real value	Estimated value	Error	Error ratio
1974	3, 638. 00	3, 630. 27	-7. 73	-0. 2
1975	3, 669. 00	3, 667. 46	-1. 54	0. 0
1976	3, 726. 00	3, 702. 23	-23. 77	-0. 6
1977	3, 773. 00	3, 785. 51	12. 51	0. 3
1978	3, 811. 00	3, 847. 52	36. 52	1. 0
1979	3, 896. 00	3, 895. 31	-. 69	0. 0
1980	3, 997. 00	3, 951. 67	-45. 33	-1. 1
1981	4, 048. 00	4, 063. 50	15. 50	0. 4
1982	4, 125. 00	4, 122. 19	-2. 81	-0. 1
1983	4, 223. 00	4, 187. 69	-35. 31	-0. 8
1984	4, 281. 00	4, 286. 90	5. 90	0. 1
1985	4, 328. 00	4, 357. 80	29. 80	0. 7
1986	4, 382. 00	4, 421. 50	39. 50	0. 9
1987	4, 452. 00	4, 487. 45	35. 45	0. 8
1988	4, 572. 00	4, 577. 72	5. 72	0. 1
1989	4, 711. 00	4, 701. 49	-9. 51	-0. 2
1990	4, 882. 00	4, 842. 16	-39. 84	-0. 8
1991	5, 036. 00	5, 009. 18	-26. 82	-0. 5
1992	5, 141. 00	5, 121. 82	-19. 18	-0. 4
1993	5, 213. 00	5, 208. 62	-4. 38	-0. 1
1994	5, 243. 00	5, 279. 00	36. 00	0. 7

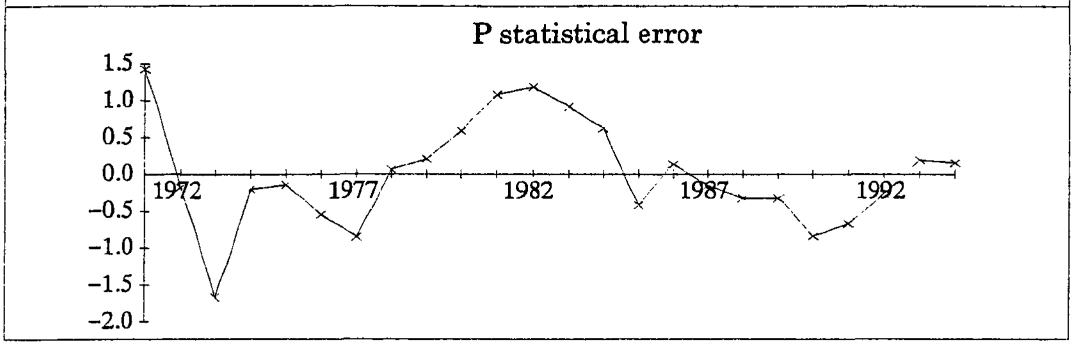
Nominal per capita compensation of employees



Trend in error	Real value	Estimated value	Error	Error ratio
1974	2, 027. 28	2, 027. 45	. 17	0. 0
1975	2, 285. 41	2, 290. 38	4. 96	0. 2
1976	2, 531. 63	2, 561. 19	29. 56	1. 2
1977	2, 782. 87	2, 765. 20	-17. 67	-0. 6
1978	2, 959. 87	2, 929. 14	-30. 73	-1. 0
1979	3, 134. 66	3, 107. 05	-27. 60	-0. 9
1980	3, 322. 70	3, 362. 82	40. 12	1. 2
1981	3, 539. 45	3, 539. 33	-. 13	0. 0
1982	3, 677. 18	3, 668. 05	-9. 13	-0. 2
1983	3, 764. 51	3, 789. 79	25. 28	0. 7
1984	3, 919. 23	3, 935. 69	16. 46	0. 4
1985	4, 068. 69	4, 072. 95	4. 27	0. 1
1986	4, 165. 17	4, 159. 53	-5. 64	-0. 1
1987	4, 261. 88	4, 253. 03	-8. 85	-0. 2
1988	4, 391. 04	4, 416. 37	25. 33	0. 6
1989	4, 586. 86	4, 585. 57	-1. 29	0. 0
1990	4, 791. 42	4, 767. 38	-24. 04	-0. 5
1991	4, 987. 86	4, 870. 28	-117. 58	-2. 4
1992	5, 025. 98	5, 016. 36	-9. 62	-0. 2
1993	5, 080. 59	5, 123. 74	43. 14	0. 8
1994	5, 142. 40	5, 205. 38	62. 99	1. 2

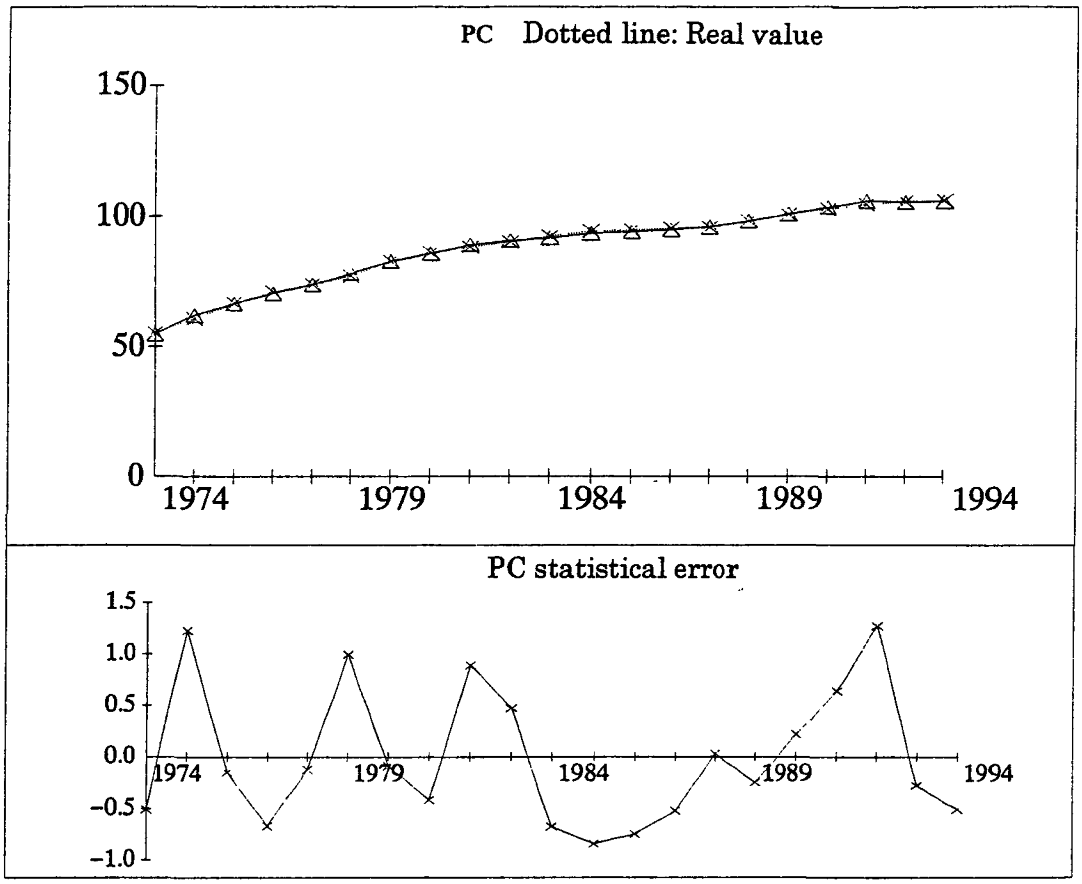
Gross national product deflator





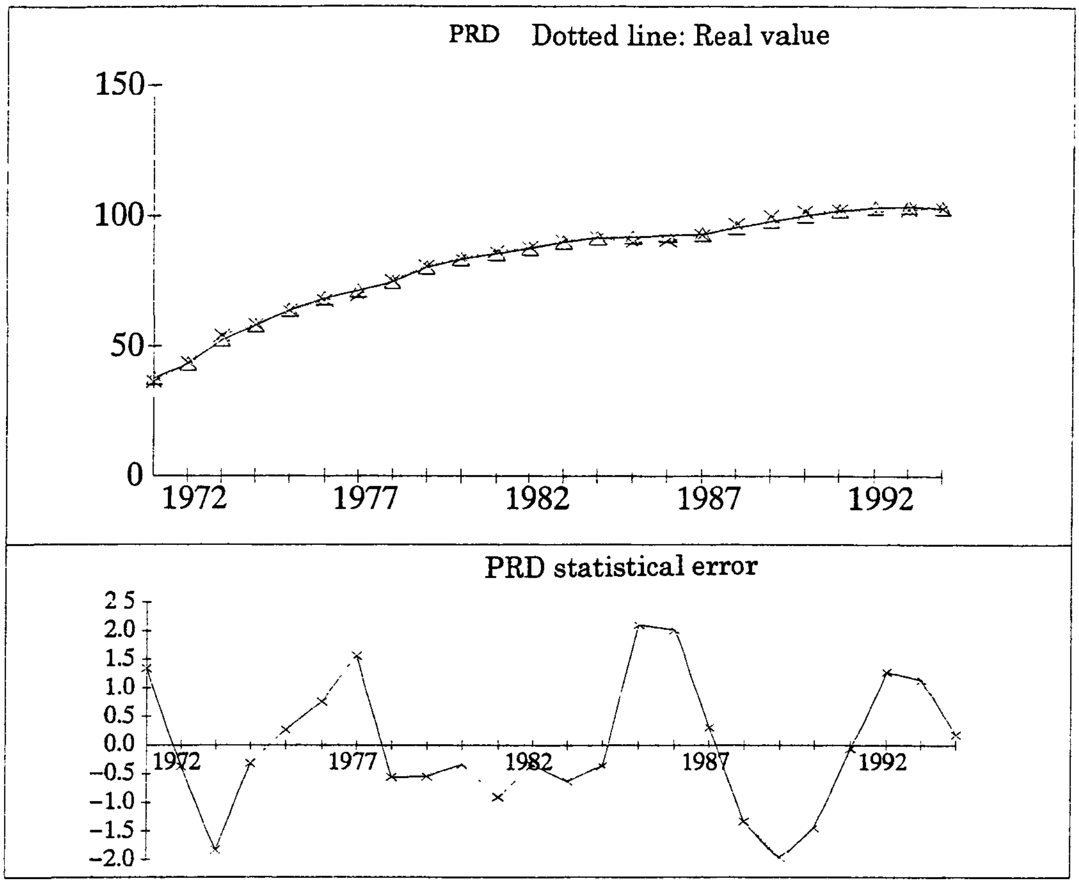
Trend in error	Real value	Estimated value	Error	Error ratio
1972	44. 220	45. 643	1. 423	3. 2
1973	50. 890	50. 709	−. 181	−0. 4
1974	60. 660	58. 993	−1. 667	−2. 7
1975	64. 200	63. 996	−. 204	−0. 3
1976	69. 560	69. 416	−. 144	−0. 2
1977	73. 850	73. 305	−. 545	−0. 7
1978	76. 880	76. 033	−. 847	−1. 1
1979	78. 940	79. 006	. 066	0. 1
1980	83. 880	84. 090	. 210	0. 3
1981	86. 500	87. 090	. 590	0. 7
1982	87. 940	89. 021	1. 081	1. 2
1983	89. 610	90. 797	1. 187	1. 3
1984	91. 980	92. 900	. 920	1. 0
1985	93. 880	94. 504	. 624	0. 7
1986	95. 250	94. 830	−. 420	−0. 4
1987	95. 250	95. 383	. 133	0. 1
1988	95. 990	95. 836	−. 154	−0. 2
1989	98. 390	98. 066	−. 324	−0. 3
1990	100. 630	100. 305	−. 325	−0. 3
1991	103. 150	102. 317	−. 833	−0. 8
1992	104. 690	104. 021	−. 669	−0. 6
1993	105. 320	105. 054	−. 266	−0. 3
1994	105. 280	105. 471	. 191	0. 2
1995	104. 810	104. 963	. 153	0. 1

Private final consumption expenditure deflator



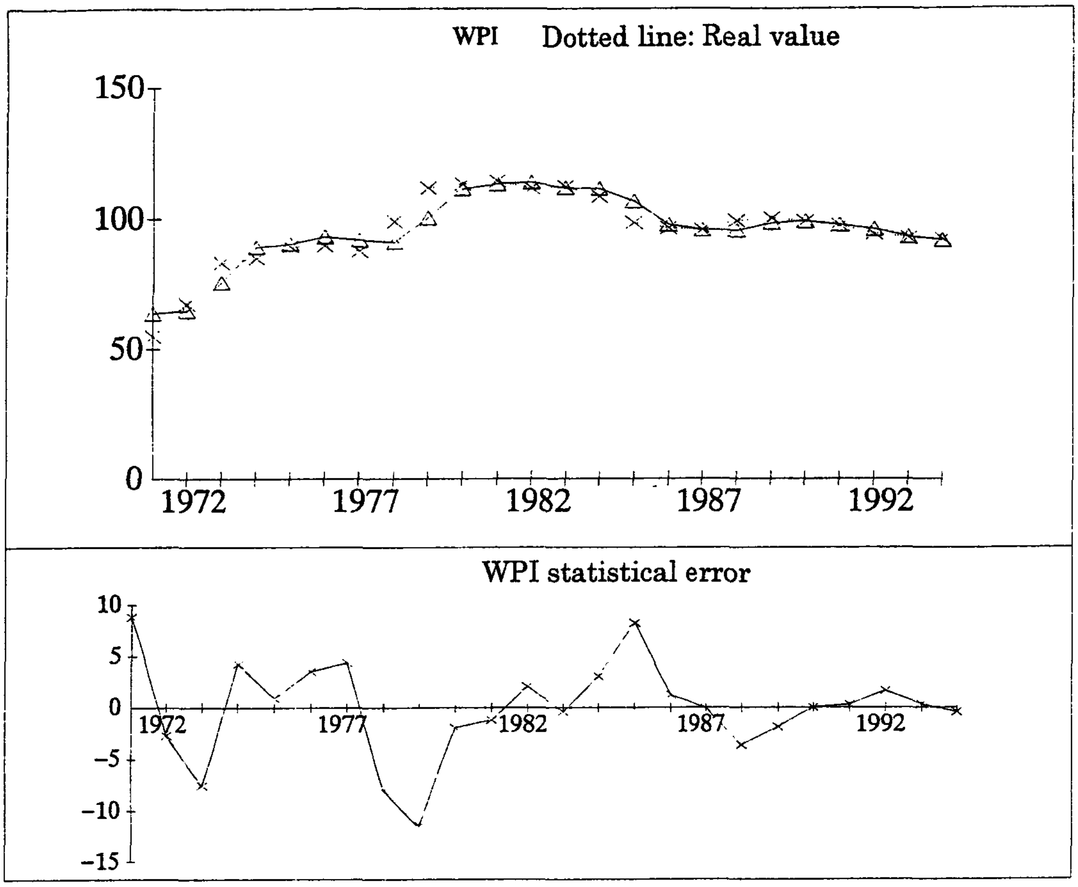
Trend in error	Real value	Estimated value	Error	Error ratio
1974	55.150	54.644	-.506	-0.9
1975	60.670	61.897	1.227	2.0
1976	66.650	66.502	-.148	-0.2
1977	70.940	70.274	-.666	-0.9
1978	73.950	73.831	-.119	-0.2
1979	77.230	78.226	.996	1.3
1980	82.840	82.753	-.087	-0.1
1981	86.150	85.734	-.416	-0.5
1982	88.280	89.171	.891	1.0
1983	90.240	90.713	.473	0.5
1984	92.560	91.887	-.673	-0.7
1985	94.330	93.489	-.841	-0.9
1986	94.690	93.944	-.746	-0.8
1987	95.300	94.779	-.521	-0.5
1988	95.800	95.831	.031	0.0
1989	98.260	98.012	-.248	-0.3
1990	100.730	100.950	.220	0.2
1991	102.950	103.591	.641	0.6
1992	104.830	106.102	1.272	1.2
1993	105.970	105.696	-.274	-0.3
1994	106.430	105.923	-.507	-0.5

R&D expense deflator



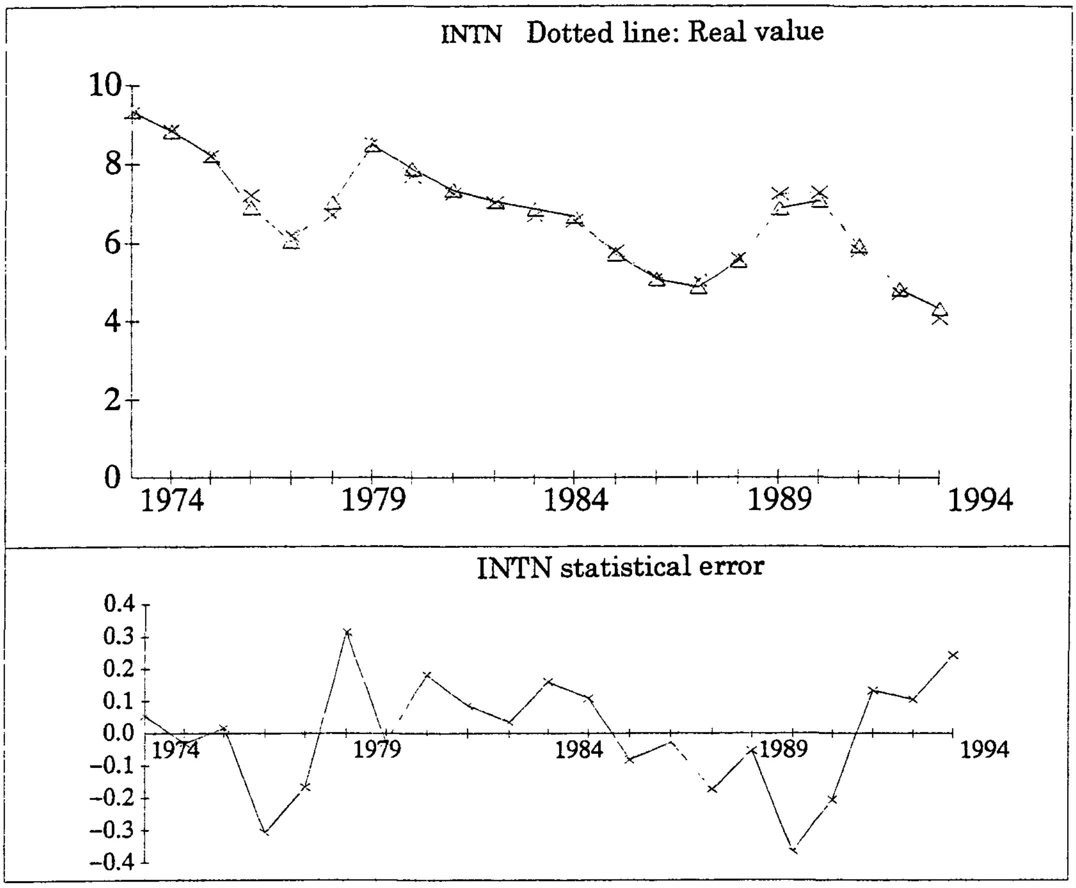
Trend in error	Real value	Estimated value	Error	Error ratio
1972	36.400	37.744	1.344	3.7
1973	43.700	43.333	-.367	-0.8
1974	54.300	52.471	-1.829	-3.4
1975	58.300	57.990	-.310	-0.5
1976	63.700	63.968	.268	0.4
1977	67.500	68.257	.757	1.1
1978	69.700	71.267	1.567	2.2
1979	75.100	74.546	-.554	-0.7
1980	80.700	80.155	-.545	-0.7
1981	83.800	83.464	-.336	-0.4
1982	86.500	85.594	-.906	-1.0
1983	87.900	87.553	-.347	-0.4
1984	90.500	89.873	-.627	-0.7
1985	92.000	91.643	-.357	-0.4
1986	89.900	92.003	2.103	2.3
1987	90.600	92.612	2.012	2.2
1988	92.800	93.112	.312	0.3
1989	96.900	95.572	-1.328	-1.4
1990	100.000	98.041	-1.959	-2.0
1991	101.700	100.261	-1.439	-1.4
1992	102.200	102.140	-.060	-0.1
1993	102.000	103.280	1.280	1.3
1994	102.600	103.740	1.140	1.1
1995	103.000	103.180	.180	0.2

Wholesale price index



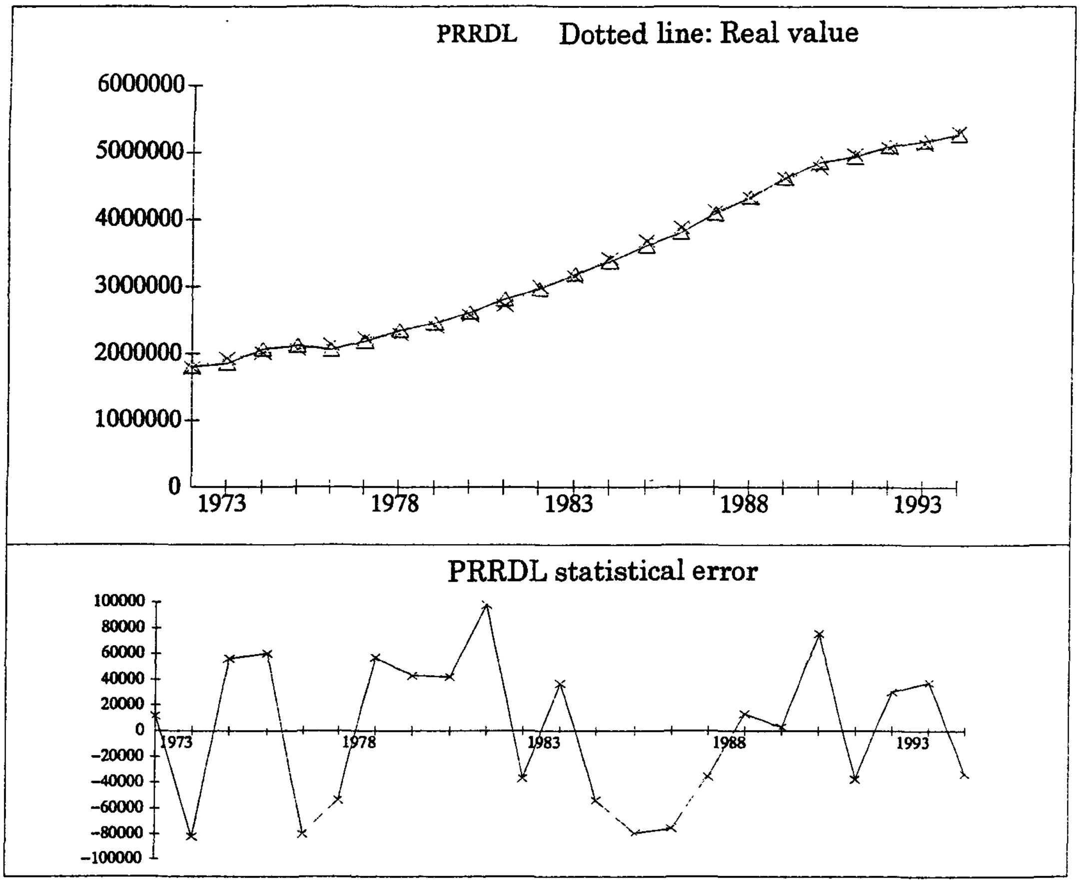
Trend in error	Real value	Estimated value	Error	Error ratio
1972	54.900	63.723	8.823	16.1
1973	67.300	64.614	-2.686	-4.0
1974	83.100	75.582	-7.518	-9.0
1975	84.800	89.082	4.282	5.0
1976	89.400	90.334	.934	1.0
1977	89.700	93.244	3.544	4.0
1978	87.600	92.005	4.405	5.0
1979	99.000	90.998	-8.002	-8.1
1980	111.700	100.278	-11.422	-10.2
1981	113.200	111.291	-1.909	-1.7
1982	114.300	113.134	-1.166	-1.0
1983	111.600	113.703	2.103	1.9
1984	112.000	111.629	-.371	-0.3
1985	108.300	111.364	3.064	2.8
1986	98.300	106.569	8.269	8.4
1987	96.300	97.554	1.254	1.3
1988	95.600	95.592	-.008	0.0
1989	99.000	95.395	-3.605	-3.6
1990	100.100	98.228	-1.872	-1.9
1991	98.900	98.933	.033	0.0
1992	97.400	97.689	.289	0.3
1993	94.300	95.965	1.665	1.8
1994	92.800	93.121	.321	0.3
1995	92.200	91.773	-.427	-0.5

Interest rates (national bank loan contractual average interest rate)



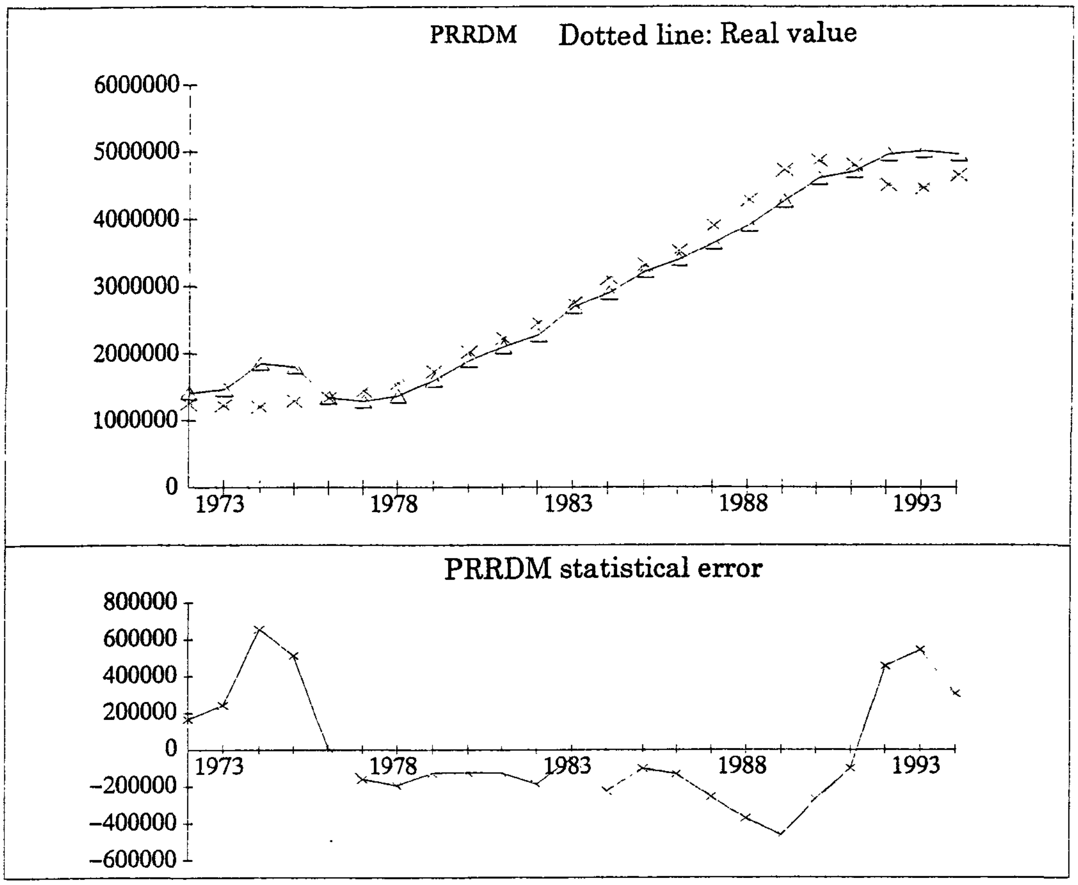
Trend in error	Real value	Estimated value	Error	Error ratio
1974	9.2904	9.3443	.0539	0.6
1975	8.8385	8.8087	-.0298	-0.3
1976	8.2062	8.2230	.0169	0.2
1977	7.2222	6.9156	-.3066	-4.2
1978	6.2214	6.0558	-.1657	-2.7
1979	6.7293	7.0435	.3142	4.7
1980	8.5220	8.4940	-.0280	-0.3
1981	7.6863	7.8680	.1818	2.4
1982	7.2523	7.3381	.0858	1.2
1983	7.0334	7.0685	.0351	0.5
1984	6.7014	6.8614	.1600	2.4
1985	6.5608	6.6692	.1085	1.7
1986	5.7787	5.6960	-.0827	-1.4
1987	5.0906	5.0622	-.0284	-0.6
1988	5.0354	4.8621	-.1734	-3.4
1989	5.5801	5.5273	-.0528	-0.9
1990	7.2338	6.8690	-.3649	-5.0
1991	7.2682	7.0631	-.2051	-2.8
1992	5.7934	5.9257	.1323	2.3
1993	4.7094	4.8155	.1061	2.3
1994	4.0780	4.3209	.2429	6.0

Real private R&D personnel expenses



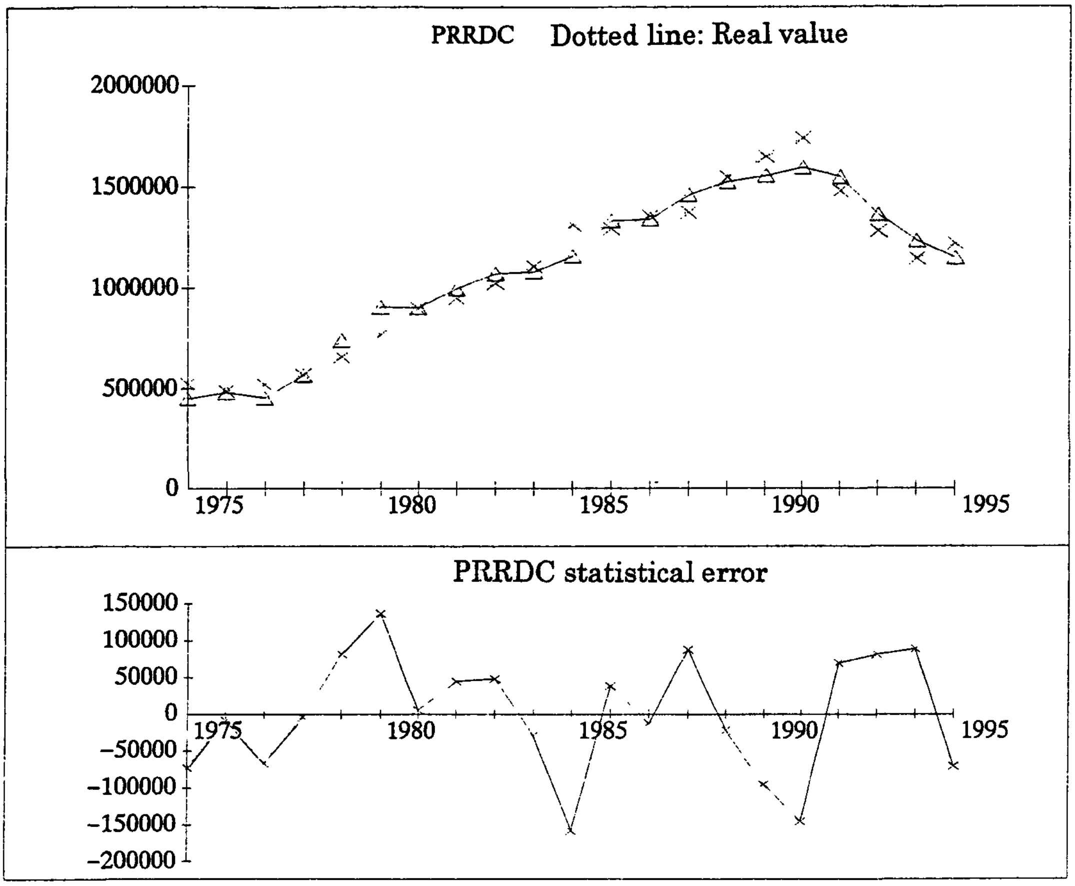
Trend in error	Real value	Estimated value	Error	Error ratio
1973	1, 788, 812	1, 800, 459	11, 646	0. 7
1974	1, 933, 987	1, 852, 116	-81, 871	-4. 2
1975	2, 011, 439	2, 067, 759	56, 319	2. 8
1976	2, 064, 372	2, 124, 785	60, 413	2. 9
1977	2, 139, 504	2, 059, 594	-79, 910	-3. 7
1978	2, 235, 178	2, 181, 699	-53, 479	-2. 4
1979	2, 292, 598	2, 349, 635	57, 037	2. 5
1980	2, 409, 294	2, 452, 402	43, 108	1. 8
1981	2, 571, 172	2, 613, 324	42, 152	1. 6
1982	2, 715, 330	2, 813, 550	98, 220	3. 6
1983	2, 997, 787	2, 961, 054	-36, 733	-1. 2
1984	3, 148, 352	3, 185, 235	36, 884	1. 2
1985	3, 420, 649	3, 366, 947	-53, 702	-1. 6
1986	3, 687, 350	3, 608, 368	-78, 983	-2. 1
1987	3, 882, 438	3, 807, 282	-75, 156	-1. 9
1988	4, 123, 487	4, 088, 153	-35, 335	-0. 9
1989	4, 322, 162	4, 335, 599	13, 437	0. 3
1990	4, 617, 036	4, 619, 954	2, 918	0. 1
1991	4, 776, 146	4, 851, 821	75, 675	1. 6
1992	4, 974, 832	4, 937, 284	-37, 548	-0. 8
1993	5, 065, 611	5, 095, 959	30, 348	0. 6
1994	5, 135, 547	5, 173, 377	37, 829	0. 7
1995	5, 302, 778	5, 269, 508	-33, 269	-0. 6

Real private R&D material expenses



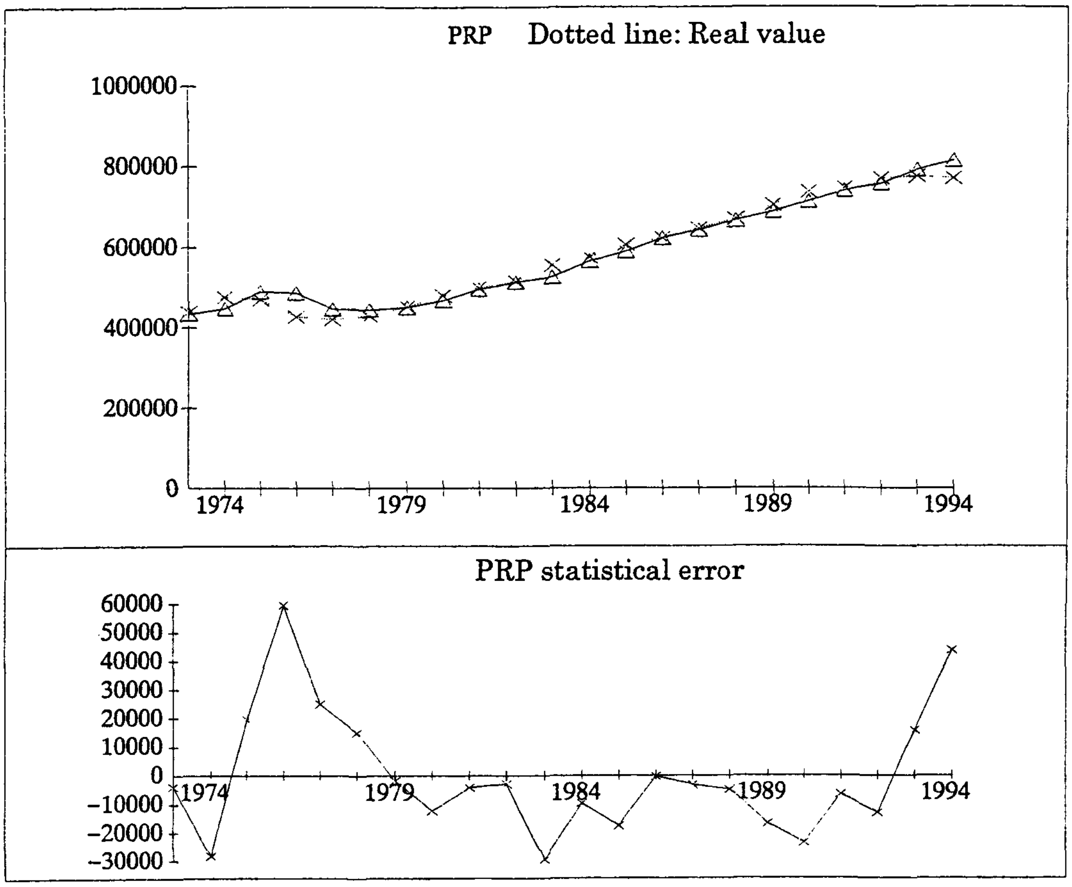
Trend in error	Real value	Estimated value	Error	Error ratio
1973	1, 247, 270	1, 412, 848	165, 578	13. 3
1974	1, 228, 932	1, 469, 319	240, 387	19. 6
1975	1, 205, 861	1, 860, 601	654, 740	54. 3
1976	1, 294, 744	1, 806, 583	511, 839	39. 5
1977	1, 338, 108	1, 350, 020	11, 912	0. 9
1978	1, 451, 673	1, 291, 202	-160, 471	-11. 1
1979	1, 567, 257	1, 372, 777	-194, 480	-12. 4
1980	1, 737, 175	1, 608, 447	-128, 728	-7. 4
1981	2, 027, 143	1, 902, 167	-124, 976	-6. 2
1982	2, 235, 117	2, 108, 535	-126, 583	-5. 7
1983	2, 465, 986	2, 279, 409	-186, 577	-7. 6
1984	2, 747, 620	2, 699, 027	-48, 593	-1. 8
1985	3, 129, 429	2, 904, 110	-225, 319	-7. 2
1986	3, 334, 396	3, 233, 849	-100, 547	-3. 0
1987	3, 541, 941	3, 409, 618	-132, 323	-3. 7
1988	3, 914, 879	3, 659, 435	-255, 444	-6. 5
1989	4, 292, 353	3, 920, 904	-371, 449	-8. 7
1990	4, 742, 976	4, 277, 737	-465, 240	-9. 8
1991	4, 885, 151	4, 618, 527	-266, 624	-5. 5
1992	4, 826, 234	4, 725, 584	-100, 650	-2. 1
1993	4, 525, 952	4, 979, 896	453, 944	10. 0
1994	4, 482, 563	5, 026, 778	544, 215	12. 1
1995	4, 668, 708	4, 974, 097	305, 388	6. 5

Real private R&D plant and equipment investment



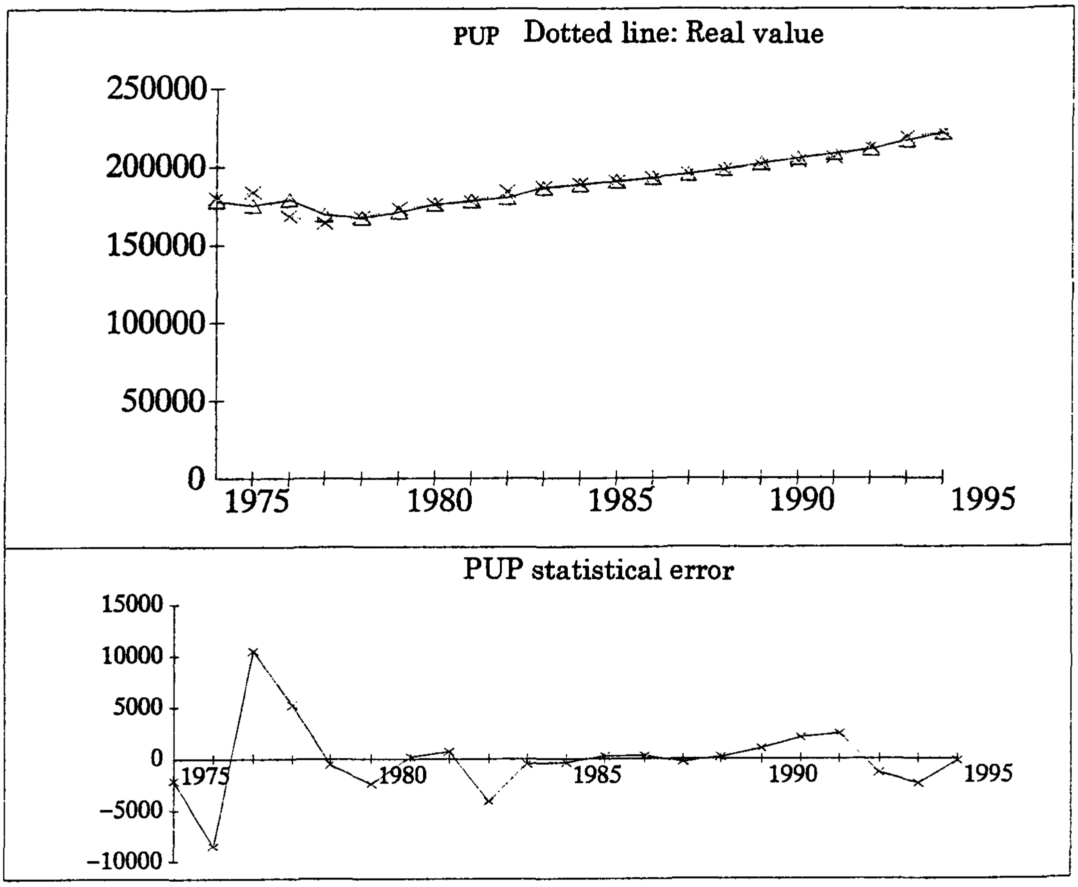
Trend in error	Real value	Estimated value	Error	Error ratio
1975	522, 509	449, 728	-72, 781	-13. 9
1976	488, 746	480, 433	-8, 313	-1. 7
1977	519, 216	452, 343	-66, 873	-12. 9
1978	568, 878	565, 180	-3, 699	-0. 7
1979	657, 836	739, 747	81, 910	12. 5
1980	767, 777	904, 692	136, 915	17. 8
1981	896, 797	902, 318	5, 521	0. 6
1982	949, 882	995, 016	45, 134	4. 8
1983	1, 020, 826	1, 069, 238	48, 412	4. 7
1984	1, 105, 638	1, 076, 772	-28, 866	-2. 6
1985	1, 313, 190	1, 155, 622	-157, 568	-12. 0
1986	1, 293, 759	1, 332, 307	38, 549	3. 0
1987	1, 3[illegible]3, 554	1, 341, 120	-12, 434	-0. 9
1988	1, 373, 003	1, 460, 700	87, 697	6. 4
1989	1, 548, 720	1, 526, 503	-22, 217	-1. 4
1990	1, 652, 777	1, 557, 556	-95, 221	-5. 8
1991	1, 743, 302	1, 598, 022	-145, 280	-8. 3
1992	1, 483, 952	1, 553, 455	69, 503	4. 7
1993	1, 284, 775	1, 366, 196	81, 422	6. 3
1994	1, 148, 061	1, 236, 794	88, 733	7. 7
1995	1, 221, 942	1, 151, 398	-70, 544	-5. 8

Number of private sector researchers



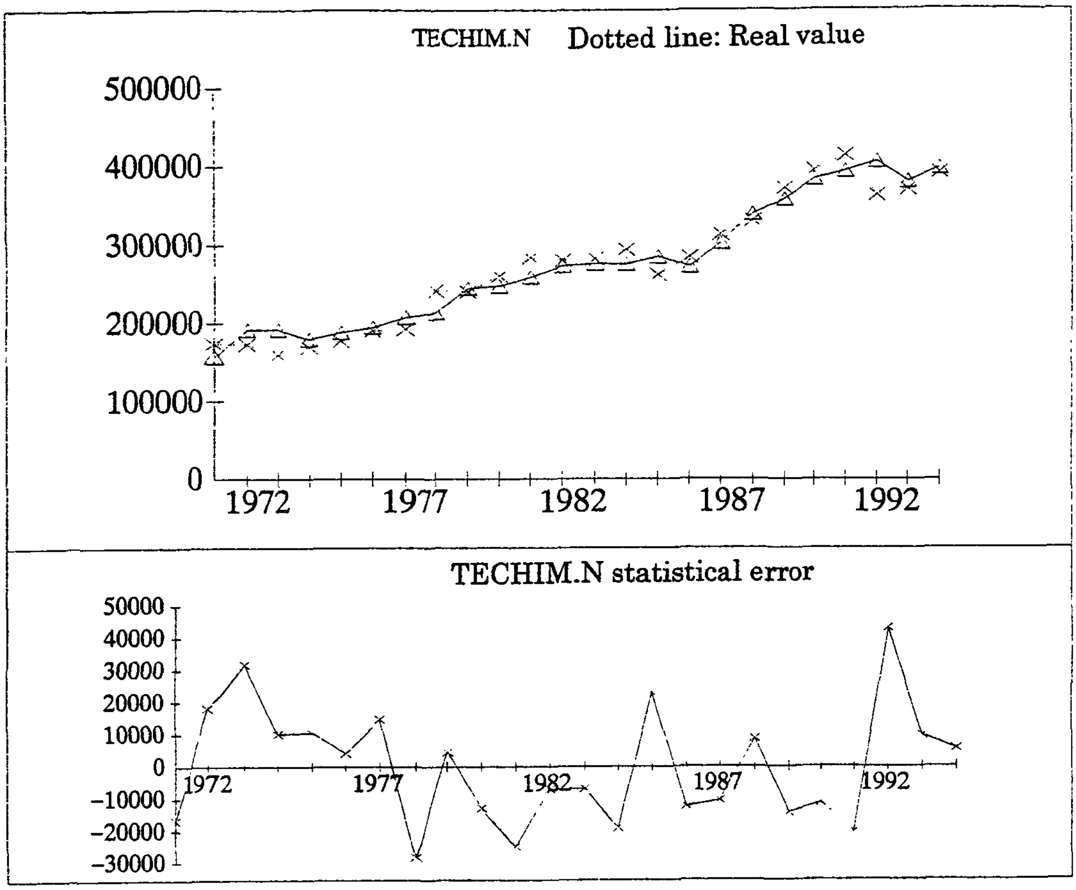
Trend in error	Real value	Estimated value	Error	Error ratio
1974	438,343.0	434,534.8	-3,808.2	-0.9
1975	475,517.0	447,214.9	-28,302.1	-6.0
1976	470,385.0	489,848.8	19,463.8	4.1
1977	427,009.0	486,362.6	59,353.6	13.9
1978	421,421.0	446,376.3	24,955.3	5.9
1979	429,171.0	444,182.8	15,011.8	3.5
1980	451,561.0	449,746.7	-1,814.3	-0.4
1981	479,466.0	467,220.3	-12,245.7	-2.6
1982	499,072.0	494,981.5	-4,090.5	-0.8
1983	515,306.0	512,503.2	-2,802.8	-0.5
1984	555,172.0	525,621.3	-29,550.8	-5.3
1985	574,656.0	564,970.6	-9,685.4	-1.7
1986	605,983.0	588,414.6	-17,568.4	-2.9
1987	622,682.0	622,392.8	-289.3	0.0
1988	646,416.0	643,071.9	-3,344.1	-0.5
1989	671,257.0	666,280.6	-4,976.4	-0.7
1990	705,158.0	688,386.9	-16,771.1	-2.4
1991	737,535.0	714,062.2	-23,472.8	-3.2
1992	747,706.0	741,194.4	-6,511.6	-0.9
1993	771,867.0	758,920.9	-12,946.1	-1.7
1994	776,321.0	792,014.1	15,693.1	2.0
1995	771,316.0	815,017.9	43,701.9	5.7

Number of public sector researchers



Trend in error	Real value	Estimated value	Error	Error ratio
1975	180,090.0	177,980.6	-2,109.4	-1.2
1976	183,451.0	174,963.0	-8,488.0	-4.6
1977	167,778.0	178,283.2	10,505.2	6.3
1978	163,569.0	168,794.3	5,225.3	3.2
1979	167,460.0	166,935.5	-524.5	-0.3
1980	173,216.0	170,804.4	-2,411.6	-1.4
1981	175,518.0	175,698.2	180.2	0.1
1982	177,205.0	177,918.7	713.7	0.4
1983	183,805.0	179,698.2	-4,106.8	-2.2
1984	186,116.0	185,625.2	-490.8	-0.3
1985	188,165.0	187,778.7	-386.3	-0.2
1986	189,966.0	190,231.6	265.6	0.1
1987	191,974.0	192,276.7	302.7	0.2
1988	194,830.0	194,530.2	-299.8	-0.2
1989	197,458.0	197,611.8	153.7	0.1
1990	200,485.0	201,487.5	1,002.5	0.5
1991	202,771.0	204,818.0	2,047.1	1.0
1992	205,361.0	207,750.0	2,389.0	1.2
1993	211,853.0	210,499.0	-1,354.0	-0.6
1994	218,301.0	215,886.1	-2,414.9	-1.1
1995	221,149.0	220,950.3	-198.7	-0.1

Nominal technology imports



Trend in error	Real value	Estimated value	Error	Error ratio
1972	173, 916.0	157, 291.8	-16, 624.2	-9.6
1973	173, 309.0	191, 469.0	18, 160.0	10.5
1974	159, 832.0	191, 619.1	31, 787.1	19.9
1975	169, 131.0	179, 209.0	10, 078.0	6.0
1976	177, 302.0	187, 892.8	10, 590.8	6.0
1977	190, 066.0	194, 241.7	4, 175.7	2.2
1978	192, 058.0	206, 852.8	14, 794.8	7.7
1979	240, 984.0	212, 747.8	-28, 236.2	-11.7
1980	239, 529.0	244, 074.0	4, 545.0	1.9
1981	259, 632.0	246, 777.0	-12, 855.0	-5.0
1982	282, 613.0	257, 914.3	-24, 698.7	-8.7
1983	279, 280.0	272, 347.8	-6, 932.2	-2.5
1984	281, 447.0	274, 651.7	-6, 795.4	-2.4
1985	293, 173.0	274, 261.8	-18, 911.2	-6.5
1986	260, 577.0	283, 542.2	22, 965.2	8.8
1987	283, 245.0	270, 993.5	-12, 251.5	-4.3
1988	312, 195.0	301, 634.2	-10, 560.8	-3.4
1989	329, 925.0	338, 503.7	8, 578.7	2.6
1990	371, 907.0	357, 549.3	-14, 357.7	-3.9
1991	394, 661.0	383, 450.7	-11, 210.3	-2.8
1992	413, 908.0	393, 623.8	-20, 284.2	-4.9
1993	362, 974.0	405, 932.3	42, 958.3	11.8
1994	370, 693.0	380, 287.6	9, 594.6	2.6
1995	391, 715.0	397, 204.2	5, 489.2	1.4