Korean Goverment R&D Expenditure Policy: An Evaluation and A Future Direction

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〈Contents〉

I. Introduction

Much Works have been done to find out relationships among R&D investment, industrial innovation, and economic growth, and to develop models from these findings aiming at describing and predicting R&D expenditure and economic development. However, these models cannot be directly adapted without modification as guidlines of R&D budget assessment and optimal allocations.

This paper, by adapting important ideas from these previous works and introducing some ideas from public expenditure theory, will develop a model to be used as a guideline for evaluation of R&D expenditure policy and analyze current Korean government R&D expenditure policy.

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2. Industrial Innovation and National R&D Expenditure

2.1 The Relationships between R&D Expenditure and Industrial Innovation

There have been numerous studies to find out and suggest optimal allocations of R&D resources to maximize industrial innovation and, in turn, economic growth. Two lines of approaches, among others, are macro-economic approach and micro-behavioral approach.

Macro-economic approach is mostly concerned about finding out correlations between aggregate economic growth and national R&D expenditures. On the other hand, micro-behavioral approach is more concerned about finding out patterns of innovations in production units. The former approach, because of its theoretical lack of explanation and prediction of behaviors of the production units in production processes, is not appropriate to use as a guideline for R&D budget allocation. On the other hand, the latter approach, even though it is successful in describing patterns of innovations in production processes, is not appropriate because of its model's limitations in linking innovation process and manager's decision-making behavior.

A theoretical model of R&D budget allocation to be used as a guideline for government R&D budget evaluation can describe and predict manager's decision making behavior and also suggest normative evaluation criteria.

2.2 Macro-economic Approaches to R&D and Economic Growth

The main concerns of these approaches are to find out and establish relationships between technological change and economic growth.(1) More specifically, they tried to estimate the contributions of technological changes to the output changes of the national economy.

Inputs consists of flows of services from labor (L), physical capital (K), the state of knowledge (G) relevant to the production such as scientific and technological knowledge (Gs), and other knowledge relevant to production (Gn), scientific human capital (Hs) and non-scientific one (Hn), and imports (M). Then, by aggregating over all activities, it can be written as $Y=f$ (L, K, Gs, Gn, Hs, Hn, M), where Y is output. The output consists partly of additions to the stock of inputs available for future use and partly of goods and services for current use.

The seven types of main outputs as additions to the stock of inputs are $\triangle$Gs, $\triangle$Gn, $\triangle$K, $\triangle$Hs, $\triangle$Hn, C (consumption gooods) and X (exports). The contribution of science and technology to growth, according to their analyses, takes a number of quite different forms. One source of growth is the increase in Gs. This comes about partly from the expenditure of scientific skills (Hs) on R&D, but it may also come about in other ways as well. The level and/or the rate of increase of Gs and Hs may affect the rate of growth of other inputs.

Even though this aggregate analysis cannot be used as a guideline for evaluation of R&D expenditure because of its apparent lack of nor-

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(1) R.O. Matthews, "The contribution of Science and Technology to Economic Development," *Science and Technology in Economic Growth*, B.R. Williams (ed.) (New York: John Wiley & Sons, Inc., 1973), pp. 1~31.
E.F. Denison, *The Sources of Economic Growth in the United States and Alternatives Before us* (New York: Committee for Economic Development, 1962).

mative criteria, this analysis gives us some insight in terms of variables and marginal increases of outputs. These variables and concept of marginal increase can be adapted in developing new model for resource allocation.

Another line of aggregate analysis is to find out the possible contribution of public and private expenditure for R&D to the growth in the residual.(2)

Common to most analyses of the contributions of researches to productivity growth is a model that can be summarized along the following lines,

$$Q=TF\ (C,\ L)$$

$$T=G\ (K,\ O)$$

$$K=\sum W_i\ R_{t-i}$$

Where Q is output, C and L are measures of capital and labor inputs respectively, T is the current level of (average) technological accomplishment, K is a measure of the accumulated and still productive research capital(knowledge), O represents other forces affecting productivity, R measures the real gross investment in research in period t, and the $W_i's$ connect the current state of knowledge. Also $K_t=\sum W_i\ R_{t-i}$ can be thought of as a measure of the distributed lag effect of past research investments on productivity.

Even though this model can be used to estimate the contributions of research to growth, we cannot get any idea about how much and in which way R&D budget be allocated.

Aggregate macro-economic analysis of research expenditure and economic growth cannot delineate individual production unit's growth potential as the result of R&D expenditure and cannot describe dynamic process of innovation and industrial development as the result of R&D investment.

2.3 Micro-Behavioral Approaches to R&D and Industrial Innovation

This approach describes the dynamics of industrial innovation of a productive unit under various conditions.(3)

Even though this approach is more concerned about strategic design of productive unit's physical facilities, process integration, material standardization, and labor specialization to facilitate industrial innovation, this model also describes the behaviors of the productive unit's R&D investments.

This approach differentiates three different stages of innovative process—that is, fluid, transition and specific. The pattern of relationships between a unit's stage of development and innovation was conceptualized by measuring rates of major innovation in each stages of production process characteristics.

Although this model can explain the patterns of product and process innovations of a productive unit, and the reason why in a certain circumstances R&D as a force for innovation be stimulated, this model has some limitations

(2) Z. Grilliches, "Research Expenditure and Growth Accounting," Williams, (ed.) *op. cit.*, pp. 59~83; Edwin Mansfield, "Rate of Return from Industrial Research and Development," *American Economic Review*, LL(2, May 1965); Jora R. Minasian, "Research and Development, Production Functions, and Rates of Return," *American Economic Review*, LIX (Proceedings Issue, 2, 1969), pp. 80~85.

(3) James M. Utterback, *Management of Technology* (Cambridge, Center for Policy Alternatives, MIT, CPA/WP-78-7, February 1978); William, J, Abernathy and James M. Utterback, "Patterns of Industrial Innovation," *Technology Review* (June/July, 1978), pp. 41-48. ; James M. Utterback, et. al., "A Comparison of Selected Industry Experience," in *Government Involvement in Innovation Process: Policy Implications* (Cambridge: Center for Policy Alternatives, MIT, CPA-78-4, May 1978).

to be further developed as normative guidelines for evaluation of R&D resource allocation.

The main limitation comes from the one axis which represents rates of major innovation.

If this model can relate production process characteristics with benefits which managers of a production unit or a society try to optimize, it may be further developed as a model to be used as a guideline for R&D expenditure policy.

As the matter of fact, this model indicates that in early phases of the product life cycle the rate of product change is expected to be rapid and operating profit margins to be large. On the other hand, firms in transition period would tend to maximize sales and market share, defining needs based on their visibility to the customer.[(4)] In specific period, product variety tends to be reduced and the product becomes standardized. Then as a progression the basis of competition begins to shift to product price, margins are reduced, and efficiency and economies of scales are emphasized in production.

Thus, if we can replace "rate of major innovation" with "benefit of major innovation", we can reconceptualize the pattern of relationships between a unit's stage of development and industrial innovation.

This model then can differentiate degree of significance of the industrial innovations in point of view of business firms and, further, automatically give weights to each innovations by measuring benefits from innovation in a certain period of time. In addition this model can be related with manager's decision-making behavior in the process of R&D budget evaluation.

3. A Management Decision-Making Approach to Government R&D Expenditure Policy

3.1 The Conceptual Framework of Maximization

The main sources of R&D resources are government and private industries. Thus, government R&D investment policy should reflect this important aspect—that is, optimal allocation of government R&D budget and optimal inducement of private R&D investments. Dynamic investment planning theory gives some clues about R&D investment assessment criteria and optimal inducement measure.

The dynamic investment planning theory[5)] suggests that the planning problem for R&D in the dynamic situation is to find the allocation of R&D budgets which maximizes the sum of project net present values and the net present values of slack subject to the condition that the sum of R&D project outlays in each period not exceed the period's R&D budget.

Thus, we must find the levels of the variable C_{it} and S_t which maximize.[(6)]

$$\sum_{i=1}^{m} B_i(C_{i1}, \cdots\cdots C_{iT}) + \sum_{i=1}^{m} \alpha_t S_t$$

$$= \sum_{i=1}^{m} \left\{ V_i(C_{i1}, \cdots\cdots C_{iT}) - \sum_{t=1}^{T} \frac{C_{it}}{(1+r)^{t-1}} \right\}$$

$$+ \sum_{t=1}^{T} \alpha_t St$$

subject to the constraints

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(4) Utterback, op. cit.; Jin-Ju Lee, "Models of Technological Innovation at a Project and a Firm Level," *Journal of The Korean Operations Research Society*, vol.3, No. 1 (June 1978), pp. 57-67.

(5) Stephen A. Marglin, *Approaches to Dynamic Investment Planning* (Amsterdam: North-Holand Publishing Company, 1963) pp. 98-100; R.N. McKean, "The Use of Shadow Prices," *Problems in Public Expenditure Analysis*, S.B. Chase (ed.) (The Brookings Institution, 1968), pp. 33-52.

(6) Marglin, *op. cit.*, pp. 101-102.

$$\sum_{i=1}^{m} C_{i1}+S_1=\bar{C}_1$$

....

$$\sum_{i=1}^{m} C_{iT}+S_T=\bar{C}_T$$

Where $\bar{C}_1, \cdots\cdots \bar{C}_T$ are seperate R&D budgets for each of T periods, C_{it} are outlays on project i in period t, $V_i(C_{i1}, \cdots\cdots C_{iT})$ and $B_i(C_{i1}, \cdots\cdots C_{iT})$ are the gross and net present value functions of project i, S_t is slack of time period t, and α_t is the net present value per dollar of slack of time period t.

The problem is equivalent to find the saddle point of following Largrangian

$$\sum_i \left\{ V_i(C_{i1}, \cdots\cdots C_{iT}) - \sum_t \frac{C_{it}}{(1+r)^{t-1}} \right\} + \sum_t \alpha_t S_t$$
$$-\sum_t \lambda_t \{\sum C_{it} + S_t - \bar{C}_t\}.$$

The Kuhn-Tucker conditions, which are necessary and sufficient to describe saddle point, are

$$\frac{\partial V_{it}}{\partial C_{it}} = \frac{1}{(1+r)^{t-1}} + \lambda_t \text{ if } C_{it}>0$$
$$\frac{\partial V_{it}}{\partial C_{it}} \leq \frac{1}{(1+r)^{t-1}} + \lambda_t \text{ if } C_{it}=0$$
$$\lambda_t \geqq \alpha_t \quad \text{if } S_t=0$$
$$\lambda_t = \alpha_t \quad \text{if } S_t>0$$

The order of magnitude of the shadow price, λ_t, depends on the general economic quality of the R&D project and the general level of the budgets.

Two important results of this analysis are that (a) C_{it} is the sum of R&D resources both from government for productive unit i and from relative individual production unit i, and (b) λ_{it}, which is a normative guideline of R&D outlay on unit i, depends on the economic quality of the productive unit i and its economic environment as well as the level of the R&D budgets.

3.2 A Hypothetical Causal Process and Its Policy Implications

R&D resources for one industrial sector come not only from government but also from private business productive units. If private business productive units take the same criteria of investment, and if they perceive that $\frac{1}{(1+r)^{t-1}}+\lambda_t$ is attractive enough to allocate more resources to R&D, than a total sum of R&D resource for one industrial sector will increase. This means that, in dynamic situation, government R&D policy should be planned in such ways that increase the shadow price λ_{it} and by so doing, induce to increase allocations of R&D investment.

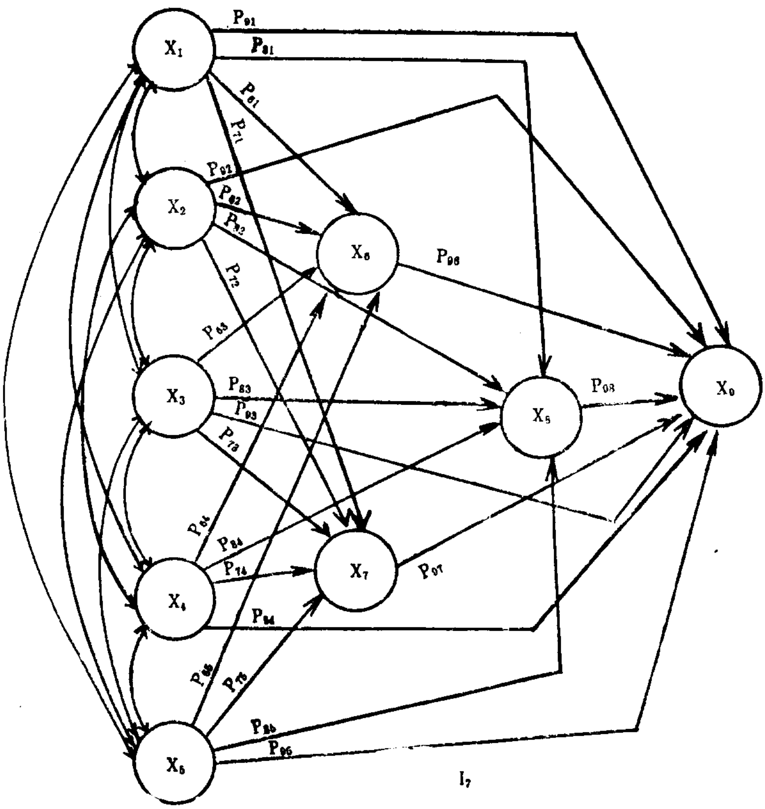
As mentioned above, the order of magnitude of the shadow price λ_{it} depends upon the general quality of the projects and the general level of the R&D budgets. Then, what does it mean by the general economic quality of the projects? This question suggests us to examine the causal processes(7) of important variables by which perceived degrees of the magnitudes of the shadow prices, λ_{it}, of managers are determined.

If an manager's perceived possibility of success of a industrial innovation as the implementation of R&D project is high both in terms of technological and commercial feasibility, then manager's perceived level of shadow price will be high.

Previous review of R&D, industrial innovation and economic growth suggests that most of the common factors affecting the innovation processes are market force (M), physical capital (K), technological knowledse (G_s) and other relevant knowledge(G_n), scientific human capital (H_s) and other relevant human capital (H_n),

(7) Fred N. Kerlinger and Elazer J. Pedhazur, *Multiple Regression in Behavioral Research* (New York: Holt, Rinehart and Winston Inc., 1973) pp. 305~331; H.M. Blalock, Jr., *Causal Models in the Social Science*(Chicago: Aldine Publishing Company, 1971).

Fig. 1. Possible Causal Path in Productive Unit's R&D Budget Determination Process



Notation

Ⅰ. →Causal Relationships

↖Possible correlation resulting from unspecified causal mechanisms

Ⅱ. X_1=K X_6=TU: Technological Uncertainty

X_2=H X_7=CU : Commercial Uncertainty

X_3=G X_8=PS : Perceived Shadow price

H_4=M X_9=B : R&D Budget

H_5=I

assisting institutions and information flow (*I*). Manager's role in integrating these factors in technological innovation processes are crucial.[8]

The causal process[9] among these factors during the productive unit's R&D budget formation can be hypothesized as following Figure 1.

(8) K. Nagaraja Rao, Linus Kim, J. Herbert Holloman, and James M. Utterback, ***Industrial Innovation, Diffusion and the Role of Institutional Supports in the Developing Context: The Case of Korea*** (Cambridge: Center for Policy Alternatives, MIT, CPA/WP76), 1976; Utterback, et. al., ***op. cit.***, p. 21.

(9) David R. Heise, "Problems in the Path Analysis and Causal Inference," ***Sociological Methodology*** 1969, Edgar E. Borgatta (ed) (San Francisco: Jossey-Bass, Inc., Publishers, 1969); Thomas R, Dye, "Methods in Policy Analysis," ***Policy Analysis*** (Alabama: The University of Alabama Press, 1979), pp. 95-108.

Table 1:

Suggested Strong Paths	Studies
K→PS→B (P_{81}, P_{98})	our previous analysis
Socio-economic infra structure[10] (H, G)→TU→PS→B (P_{62}, P_{63}, P_{86}, P_{98})	Utterback, 1978 Kim, 1977 Rao, 1977 William and Utterback, 1978
Market Force[11] M→CU→PS→B (P_{74}, P_{87}, P_{98})	Utterback, 1978 Von Hippel, 1976 Gustafson, 1978
Information Flow[12] I→TU→PS→B (P_{65}, P_{86}, P_{98}) I→CU→PS→B (P_{75}, P_{87}, P_{98})	Sirbu, et al., 1978 Utterback, 1977 Kim, 1977 Rao, et al., 1976 William and Utterback, 1978

The degrees of correlations among the external variables (K, H, G, M, and I) and the magnitude of the path coefficients are empirical questions in each individual productive unit of a national economic system in specific period of time. Even though the magnitudes and significances of these path coefficients are not empirically tested, there have been some studies on implicit path processes affecting manager's perceptions during technological innovations and R&D budget formations as shown in Table 1.

The implication of suggested strong paths is that government R&D policy should be in such a way that government R&D expenditures strengthen the external variables and reinforce path processes suggested so that managers perceived shadow prices for relevant project be increased.

4. An Evaluation of Korean Government R&D Policy

4.1 Trend of R&D Investment

Amounts of Korean R&D expenditure have increased during the past several years. In 1977, a total of R&D expenditure was amounted ₩108,285 million (₩500 = US$1) and this amount is nine times larger than that of 1972.[13] However, the portion of R&D expenditure for GNP is only 0.71%. This portion of R&D expenditure for GNP is very low compared with those of developed countries such as U.S.A., Japan, etc.

Among this total amount of R&D expenditure,

(10) Linsu Kim, *Stages of Development of Industrial Technology in a LDC and Their Policy Implications* (Cambridge: Center for Policy Alternatives, MIT, CPA/WP-77-12, 1977); K, Nagaraja Rao, *Direct Government Intervention in Technological Development: An Examination of Selected Country Experiences* (Cambridge: Center for Polic Alternatives, MIT, CPA/WP-76-14, August 1971); William and Utterback, *op. cit.*; Utterback, *op, cit.*

(11) E. Von Hippel, *Industrial Innovation by Users: Evidence, Explanatory Hypothesis and Implications*, (MIT, Sloan School of Management, WP #857-76, May 1976); Thane Gustafson, *Why Does the Soviet Union Lag Behind the United States in Basic Research* (Occasional Paper of the Center for Science and International Affairs, Havard University, September 1978); Utterback, *op. cit.*

(12) Marvin A. Sirbu, Thomas J. Allen, Edward B. Roberts, and Treitel Robert, *Technological Change and The Traditional Firm: Implications for Government Policy* (Cambridge: Center for Policy Alternatives, MIT, CPA-78-9, 1978 ; Daniel Rich, Marvin Sirbu, and James M. Utterback, *Strategic Alternatives for Energy Conservation* (Cambridge: Center for Policy Alternatives, MIT, CPA-77-1, February, 1977); Rao. *et. al. op. cit.*; William and Utterback, *op. cit.*

(13) Korean Ministry of Science and Technology, *Science and Technology Annual*, (1978), p. 288.

₩108,285 million in 1977, ₩51,705 million which is accounted for 47.75% comes from government and remained ₩56,580 million comes from private organizations.[14]

The implication of this pattern of R&D investment is that the perceived shadow prices of R&D investments in Korean Government as well as private business compared with those of other investment alternatives were very low. Especially it might be true for the private industries. However, there are some indications that the perceived shadow prices for R&D investment of private firms will be changed. First of all, the developed nations begin to consider Korean economy as a competitor in international economic markets so that they may not offer their developed technologies to Kerea as they have done in the past. In addition to this, labor costs in Korea are increasing very rapidly in recent years. Therfore, Korean firm's relative competing power in labor intensive industries is decreasing very rapidly in international markets.

These factors may affect in a way to raise the perceived shadow prices of R&D projects of privates firms compared to other investment alternatives in coming years. Even though this may be true in future, Korean government must take possible other measures to raise the managers' perceived shadow prices of R&D projects in order to economically motivate private firms to increase R&D expenditure.

4.2 Infrastructure for R&D

Human resources for R&D are very scarce in Korea not only in terms of absolute number but also in terms of relative number compared to other developed contries.

As it can be seen in Table 2, average number of researchers in business research organizations was only 11.7 and total number of Ph.D. degree holders for industrial R&D research was only 48 in 1977. The proportion of researchers for national population was 0.29 person per thousand population in Korea. This figure is very low compared with 2.3 person in Japan(1975), 2.5 person in U.S.A. (1974), and 3.6 person in USSR (1974).[15]

The level of scientific and technological knowledge as an economic infrastructure for R&D cannot be directly measured here. However, it can be guessed by the government efforts related with previous R&D expenditure patterns. First of all, among the ₩108,285

Table 2. Personnel Engaged in R&D

Types of Organizations	No. of Organizations	Researchers	Average Res. Per Org.	Degree		
				Ph.D	MS	BS or under
Total	626	12,771	20.4	2,882	3,010	6,879
Gov't and Public Res. Inst.	101	2,506	24.8	140	467	1,899
Non Profit Org.	31	1,533	49.4	235	398	900
Uni. & Col.	183	4,836	26.4	2,459	1,964	413
Companies	311	3,896	12.5	48	181	3,667

Source: MOST, *Science and Technology Annual* (1978), p.17.

(14) *Ibid.*, p.15.

(15) United States, National Science Foundations, *National Patterns of R&D Resources* (NSF 76-310), p.28.

million in 1977, research institute performed 23.8%, nonprofit organization 32.6%, private companies 38.5% and universities only 5.1%.[16]

Even though the role of research instittute in developing nation is very important, it is too unbalanced in R&D budget allocation among research institutions, non-profit organizations, and universities. Because of the reason that universities cannot have performed researches, its function of knowledge production may not have performed adequately. Obviously, graduates from universities and colleges cannot have been trained properly in this circumstances. For an example, total amount of R&D budget for the researches in departments of physics in Korea was ₩31.3 million (US$62,600). Among the total number of 466 professors and lecturers in the field of physics, only 40 professors and lecturers received research grants in 1976. This means that only 8.6% of professors and lecturers in the field of physics received research grants. Furthermore, average research grants per researcher in the field of physics was ₩781,000 (US $1562) in 1976.[17] No reasonable men can consider this is an appropriate amount of research grant for science of physics which requires huge amount of expensive modern research equipments.

According to these analyses, it will be sufficient to conclude that government R&D policy was not appropriate to enhance socio-economic infrastructure to motivate business managers in such a way to increase their R&D budgets via reducing their perceived technological uncertainties and via increasing their perceived degrees of shadow prices of R&D investments.

4.3. Market Force and R&D

Market imperfections are generally related with commercial uncertainty. There are two major sources of market imperfections in Korea. First one is the lack of competition mainly because of the shortage of goods and the other one is the lack of mechanisms of systematic information generation for consumers and feedback of consumer opinions to managers.[18] Among these two market imperfections, latter is relevant object for goveroment R&D expenditure policy.

Until now, Korean government has not have any clear R&D effort to ease market imperfection via systematic generations of market informations for consumers and via creation of feedback channel of consumer opinions to business managers. Thus, the lack of systematic feedback channel of consumer opinion may have been some important causes of commercial uncertainty for the some new products. Under the conditions of general shortage of consumer goods and production goods[19] except few light industrial goods, and lack of consumer opinion feed-back, business managers may perceive the shadow prices of alternative investments such as expansion of existing production facilities higher than those of new R&D investment.

4.4 Information Flow and R&D

There are two major information flows related

(16) MOST, *op. cit.*, p.289.

(17) Korean Ministry of Science and Technology, *Science and Technology Annual*, (1977), p.214.

(18) Another dimension of market imperfection is the identification of consumers for new products from industrial innovations. The government policy related with this market imperfection is more closely related with procurement policy.

(19) The shortage of consumer goods and production goods have been most of the important topics of daily news papers in Korea. See for example, Han-Kuk Ilbo, October 31, 1978.

with R&D and innovation. The first one is the information flow among research labs of university, government and non-profit organization, and industry.[20] The other one is the information flow from abroad to domestic research organizations and industrial research labs.

A total number of 174 Ph.D degree holders are working in various government research laboratories. Among them, 7 researchers are working for basic science labs, 76 researchers for agricultural science labs, 16 researchers for engineering applications, and remained 75 researchers for medical science labs.[21]

This statistical indicator alone is sufficient to say that government researches in the field of basic science and engineering applications have not been so active.

On the other hand, there were a total number of 183 research labs attached to universities. Among them, 45 labs were for engineering research, 48 for basic science, 40 for agricultural research, 39 for medical research. A total amount of research funds for university labs was ₩5,482 mlilion which was 5.1 percent of total national R&D fund in 1977 so that average research fund per lab was ₩29.95million.[22]

These figures show us that research activities in university labs have been limited only for small scale and sporadic researches except a few prestigeous university labs such as Engineering College of Seoul National University and Korean Academy of Science.

As previous analysis indicated, research activities of industrial labs have been very inactive.

The main thrust of governmental support have been put into the non-profit R&D institutions such as KIST(Korean Institute of Science and Technology), KORSTIC(Korea Scientific and Information Center), etc. Recently, Korean government have established five strategic research institutes as direct spin-offs from KIST.

These non-profit research institutions used ₩35,335 million which is about 32.6 percent of total national research fund.[23] Among these nonprofit research institutions, KIST and KORSTIC have been most active.

KIST's R&D activities in the 1960's were directed toward the solution of simple practical in-the-field problems arising in the courses of technology transfer or production process. The 1970's have added higher level technological problems such as productivity improvement, cost reduction, domestic raw material development and imported technology improvement to serve large industrial firms.[24] On the other hand KORSTIC has conducted variety of basic services such as classifying, abstracting, translating, etc., and given special attention to service in Korean language by publishing indices and abstracts and alerting users to resources serving specialized needs.[25]

It is fair to say that KIST is the major R&D institution that is designed to provide industry with direct technical assistance in the area of international transfer, adaptation, development and, in some cases, pilot demonstrations of new technology, while KORSTIC is the major technical information center that provides a technical data base for industry use.

However, their roles have been relatively restricted to international transfer and adaptation of technology so that few large scale innovative

(20) Rao, *op. cit.*, p. 18.
(21) MOST, *op. cit.* (1977), p. 18.
(22) MOST, *cp. cit.* (1978), pp. 22-23.
(23) *Ibid*, p. 15.
(24) Rao and Kim, *op. cit.*, p. 25.
(25) *Ibid.*, p. 26.

researches have been carried.

Because of these reasons, there has been one way flow of information from non-profit research institutes to industries, and no reciprocal information flows among university labs, industry labs, government labs, and non-profit institution labs. A serious problem is that there is no information recepter as a counterpart in industrial organizations. Furthermore, the contents of informations were relatively limited to the transfer of foreing technology and research institution is, at best, two steps removed from the market for new products.[26]

If business managers understood these situations, their perceived technological uncertainty as well as commercial uncertainty for the results of domestic R&D might be high so that their perceived shadow prices of R&D investments were very low.

5. Conclusion—A Future Direction of Korean Government R&D Policy

Several conclusions can be drawn from this analysis for the future direction of Korean government R&D policy. First of all, because of the changing international and domestic economic conditions in Korea, the overall shadow prices for R&D investment may have been increase continuously during the 1970's. However, the portion of R&D investment over GNP which was around 0.7% has not been changed. A comprehensive comparative study to estimate shadow prices for major important investments, even crude level, may be preferable to make correction for the national investment priorities. This study may lead to increase the overall portions of R&D investment far over 0.7%.

Second, dynamic R&D investment plans should be made to motivate industrial managers economically in such a way to increase their R&D investments via changing their perceptions on shadow prices of R&D investments.

Third, this analysis suggests some possible ways to increase industrial manager's perceived shadow prices of R&D investments as following.

(i) More emphasis for future R&D investment should be given to university labs to activate their unused research talents so that socio-economic infrastructure for innovation should be increased.

(ii) R&D investments for systematic generation and dissemination of informations for consumers and for establishment of feedback channel of consumer opinions to industrial managers should be increased.

(iii) Information flows among researches of government labs, industry labs, non-profit research institutios, and universities should be facilitated gradually by collaborative research works and exchanges of researchers among different labs.

(iv) In order to stimulate to establish research labs in industry, government should device special policy measures such as tax exemption for R&D investments for the certain period of times of early stages of new establishments of labs, subsidies for imports of research equipments, and special patent policies.

Even though this paper focused only on R&D policy, real effectiveness of R&D policy can be increased by the optimal combinations of other governmental policy measures such as government tax policy, procurement policy, patent policy, and manpower policy.

(26) T. Higgins, "Innovation Strategies for Successful Product and Process Commercialization in Government R&D," *R&D Management*, 7(1977), pp. 53-59. ; Sirbu, *op. cit.*, p. 53.