Development of Input-Output Model for Science and Technology

- Numerical Evaluation and Policy Implication -

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1. Significance of an Input-Output Model for Science and Technology

This research was done by the First Research Group of National Institute of Science and Technology Policy over the three years from 1989 to 1991.

It is needless to say that the post-war Japanese economy always had an export-oriented structure, starting from a priority production system for iron and coal, shifting to development of heavy industries, such as petrochemical and shipbuilding, and then, based on this vertically integrated system, to development of the automobile industry and the home appliance industry.

As such, there is no doubt that the manufacturing industry has been playing the leading part in the development of Japanese industries, but at the same time it cannot be overlooked that in the background there were severe competition among enterprises and also technological innovation. For the latter in particular, the manufacturing industry after the war to 1960s concentrated on how to 'catch up European and American technologies'. Nowadays, as Japan gets more competitive in exporting, Europe and America are increasingly criticizing Japan as 'a free rider on their technology' and beginning to change their policies on intellectual property rights. In these circumstances, Japan needs to develop its own technology. Significance and evaluation of R&D are also important in considering policy and business management.

Such a way of thinking has already been spreading in Europe and America. For example Freeman and others in UK are advocating the idea of 'technology economy network'. But this idea cannot be said to have reached the stage of demonstration research yet.

So far, economic policy has been deployed mainly on financial policy and fiscal policy. On the other hand, science and technology policy has been rather consumed in coordinating the inner structure of science and technology activities and in forming public acceptance for ultra-long-term research and development areas.

Toward the 21st Century, considering the magnitudes of influences that uneven distribution or uncertainty of scientific and technological knowledge would have on our society and economy, we need to clearly show the active role of science and technology policy for macro economy.

To grasp the relation between activities in science and technology and their economic applications, this Research Group chose to start with the idea of technological innovation by Schumpeter and the idea of interdependence of technologies by Leontief.

The input-output model for science and technology in this research has the following viewpoints in the background.

2. Relation between R&D Activities and Corporate Actions

Similar to the models for macro investment and production, input-output analysis for industry also has a long history since Leontief. But R&D activity is an investment in a different time point in uncertain future, and one cannot assume any linear relation like the one between investment and production. Therefore we first have to examine the framework of how we should deal with it. In the first report of this research, we first examined the framework of the table form that was obtained by adding items of 'future property' and 'knowledge stock' to the conventional input-output table for industry. Since it was needless to say that the process through which R&D produce results was dynamic one, we examined not only the input-output table for industry but also its model.

This research aims at nothing but demonstration analysis. Therefore, before expanding the input-output table for industry, we surveyed enterprises, using interview and questionnaire on their project. We asked: (1) How much they invested in time, money and human resources; (2) Whether the project succeeded or failed; and (3) How much result was obtained after the completion of the project. We asked about projects from the late 1970s to the early 1980s. The results of the survey were summarized in an interim report in the second year (fiscal 1990): (1) On project base, we observed a relation between the amount invested in R&D and the first year investment in production facilities brought by the project (which was used as an indicator of result), and the relation was that the latter was proportional to the 1.25-th power of the former; (2) Similar analysis on the data obtained from a similar survey (of projects in the 1960s) in the past by the meeting of science and technology and economy also showed the same coefficient, the 1.25-th power. This means that there was a fairly stable scale-merit in past R&D activities, which is an interesting result.

The survey was conducted again in the third year, but this time the subjects were those projects that were started in the 1980s. In this case, (3) investment in R&D and investment in production facilities from the projects had a relation that the latter was proportional to the 1.086-th power of the former. This means, the scale merit of R&D has been somewhat decreased in recent years. Even though the number of samples was very small, the results mentioned above can be regarded as an important first step, because there is no other example of demonstration analysis like this. Furthermore, we will need to examine a method to deal with the non-linearity of results of such investments.

3. Formulation of Input-Output Table for Science and Technology

At present, statistics provided by the Management and Coordination Agency are the only available statistics about R&D from the macro viewpoint that can be combined with an input-output table for industry. But they do not strictly match with the Integrated Classification of Industry and survey subjects. If overall consistency in these numerical values were sought for, it would need a large-scale investigation, which is not necessarily the purpose of this research. We keep this problem pending until survey methods and statistics on R&D activities are unified in future. Thus we integrated the input-output tables for industry from 1970 to 1985 into 23 sectors of industry, 7 sectors of final user, and 5 sectors of added value, according to the statistics of science and technology by the Management and Coordination Agency. Once the integration of sectors in statistics by the Management and Coordination Agency and in input-output tables for industry is determined, it is relatively easy to integrate these two. Here we should pay attention to the following points. That is, money is paid from columns to row sectors, but in the R&D statistics by industry by the Management and Coordination Agency, money is paid from rows to columns. Therefore the latter should be matched by transposing the matrix.

The basic idea adopted for this research was that stock of R&D up to term t produces result in term t+1 and later, becoming actual as changes in capital investment and intermediary input. Therefore we need to show not only the flow but also the stock explicitly in the table. And the stock should of course be materialized.

Here, based on the Management and Coordination Agency statistics, the R&D capital investment, raw material and personnel expenses for the six years up to the year before the year of the input-output table for industry were materialized by GDP deflator and piled up to obtain the stock.

Based on the above, we adopted the table form shown in Figure 1.

Here we indicated only two points of time, term t and term t+1, but it can be expanded similarly to three or more terms. This table form explicitly show the flow in that input in R&D activities in term t has an impact on formation of capital through R&D stock. From the standpoint of policy, effects of subsidy and capital formation on R&D are shown as a closed loop in the model.

For such macro data, we similarly analyzed the relation between investment in R&D and investment in production facilities. The result was that the latter was proportional to the 0.35-th power of the former. From the macro point of view, this drop in coefficient is natural because it includes failures and basic researches that were not directly connected to the project. However, the meaning of this numerical value was left to further study.

Furthermore, applying the restricted least squares method to the relation between investment in R&D and input coefficient, and developing an algorithm to add modification, we tried to predict the input coefficient for 1990. We also calculated production-inducing coefficient. The result indicated tendencies of increased investment in buildings and decreased income for employees.

As mentioned above, this research is just a beginning, because we had to examine both the basic methodology and data from scratch. Especially, we could hardly touch the problem on 'human resources' which is the core to carry out research activities in science and technology

However, this research is practically the first demonstration analysis on R&D and production activity. Such research has been seldom done so far, even though its importance has been pointed out. Therefore we may say that the significance of this research as a starting point toward deeper research in this direction is not small at all.