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Hirotada Kohno
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Public Investment Criteria

Using an Interregional Input-Output Programming Model

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This book is dedicated to the memory of
Professor Dr. Yasuhiko Oishi

Preface

When we were attached to the Institute of Socio-Economic Planning, University of Tsukuba, we desired to have a platform, with which our research results could be published without limit of pages. In that time, an article was generally forced to be published within 15–20 pages and we needed more than 40 pages because our works were based on an innovative simulation model of huge scale and their inputs as well as outputs were massive. It was a general current in regional science and related fields that scholars wrote shorter articles rigorously and published them in main stream of regional science journals. The implicit or explicit restriction set by journal editorship in that day was prohibitive for publication of the research results based on the philosophy, on which The Institute was newly established in the University of Tsukuba. It said that scholars do inter- and multi-disciplinary studies and return their research results for the society in order to, e.g., fix real issues and conflicts, make policy proposals, and eventually contribute for development of society. For this, we had requested Professor Dr. Jan Tinbergen to write a foreword through the good offices of Professor Dr. Peter Nijkamp. Then, a title of illusory journal ought to have been launched is *The Tokyo Journal of Large-scale Regional Modelling.*

It is a felicity for us that the monograph series *New Frontiers in Regional Science: Asian Perspectives* had been launched by the innovative undertaking of Springer Nature (Co.) in cooperation with the Japan Section of the Regional Science Association International (JSRSAI), having been admitted of the amazing conspicuous developments of JSRSAI during those 50 years.

In this volume of seven chapters, several studies which were kept within doors for more than 30 years now have been published to be able to see the light of day in the right way. Here, we express our sincere gratitude to Springer Nature above all.

During the 10 years from the latter half of the 1950s to the early 1960s (1957–1967), H. Kohno (one of the authors) had been attached to the Japan Highway Public Corporation and engaged mainly in the preparation of Loan Materials which had been submitted to the World Bank with the project of the Mei-shin (Nagoya-Kobe) Expressway and To-mei (Tokyo-Nagoya) Expressway. In other words, the

preparation work was "Measurement of economic effects of public investment and the derivation of public investment criteria."

The former was dealt with in the first volume in this series, so this volume deals with topics focusing on the latter. What is public investment criterion? It is apt to be taken as a benefit–cost analysis in a conventional sense, which is still nowadays adopted by practitioners. However, it had been so often pointed out that the conventional benefit–cost analysis has many essential rudimentary defects and limits. For example, the conventional benefit–cost analysis neglects: the scarcity of allocated public fund, which means that the analysis has no idea of the opportunity cost of public fund; dynamic optimization of the streams of returns through re-investment of returns in the future, the scope of the economy by implementing several related projects, etc. So, from the first, our concern had been shifted to fix those defects inherent to the conventional benefit–cost analysis and to develop a more elaborate and sophisticated model, the second generation, based on what was initiated by Steiner=Marglin. It is dealt with in Chap. 3. The model is formulated as the maximization of an objective function being subject to resource fund allocation constraints.

Nevertheless, in Chap. 1, various themes are dealt with, i.e., superiority or inferiority of the benefit–cost *ratio* criteria vs. benefit–*less*–cost criteria, the present value method vs. internal rate of return method (Hirshleifer), and standardization of various criteria (Mishan). Chapter 1, in a sense, makes a comprehensive survey of the past studies on the benefit–cost analysis.

In Chap. 2, we will explain a typical process of applying the conventional benefit–cost analysis to the evaluation of Mei-Shin and To-Mei Expressway in the 1960s. It is still useful for readers who are in charge of the proposal of public investment projects of huge scale.

In Chap. 3, as mentioned above, the application of sophisticated Steiner=Marglin model to the public investment criteria of expressways in Japan is dealt with, in which built in are technical constraints such as preemptive right of public sector, incompatibility of location and transport modes, indivisibility, lumpiness, reflection of various opportunity costs of investments on the objective function (named as—supra-marginality), scheduling project implementation on the time horizon of multi-periods (evasion of fault due to myopic policy). The mode is formulated as an integer programming model. The solution to the model is obtained by application of the usual LP algorithm with the *combinatorial method.* In Chap. 3, however, the measurement of economic effects must be completed in advance and the values are given to the model that solves the optimal public investment criteria, on which investments shall be implemented with a scarce investment fund.

In the late 1960s, one of the urgent topics in the business world was how to determine optimal shares between investments into the public sector and the private sector. It was raised by the economic community because they realized that the social infrastructures, especially transportation infrastructures at that time were out-of-date, and the lack of social infrastructures of high quality would be serious bottlenecks for the economic growth which were expected in the 1970s. Also, motorization was

about to start and optimal shares between investment into transportation infrastructures of railways, maritime, and roadways were urgent topics in the transportation economics association as well as among related departments of the central government.

In Chap. 4, the simulation model based on interregional input–output model of competitive-import type is formulated as a linear programming model. It was a cutting-edge model with the following features: "shipment activities" are formulated in order to simulate interregional trade patterns reflecting impacts of public projects such as expressway construction while it is different from Moses's model that transportation sectors explicitly specified in the input–output structure; and the public investment criteria is rightly embodied in the model to take into account imputed prices (or, opportunity costs) of injecting scarce public funds to possible investment targets. Imputed prices are critical indicators in order to pursue the optimality of solutions to a linear programming model based on the simplex algorithm. The model is applied to the above practical agendas. It is yet a static and prototype model, but the above-mentioned critical defects inherent to the conventional benefit–cost criteria were completely and consistently fixed. The measurement of economic effects and the identification of optimal investments targets are simultaneously solved by taking into account their impacts on the whole national economy through changes in interregional trade patterns. It was the first work in which the optimal investment shares are shown between the public sector and the private sector as well as between transportation infrastructures of railways, maritime, and roadways, based on the economic rationality of opportunity costs. Readers will confirm that the economic rationality is presented as the equalization of imputed prices that are associated with constraints, such as transportation infrastructure constraints, production capacity constraints, and scarce public fund allocation constraint, which could become bottlenecks for the economy to further grow, and can be directly fixed by the injection of scarce public funds, or indirectly fixed by, for example, changes in interregional trade patterns.

It can be said that the models developed in Chaps. 3 and 4 had achieved some success in that they are applicable to practical agendas of that day, and have shown quantitative (and objective) answers to the debated matters among related stakeholders qualitatively (and subjectively). However, the models had space for further improvements and developments. In Chap. 5, subjects for possible development and improvements of the models are discussed.

In Chap. 6, as one of the directions discussed in Chap. 5, the small-sized model of five regions, five industries, and three transport nodes developed in Chap. 4 is enlarged to incorporate ten regions, ten industries, nine means of transport. This was a practically useful model by taking advantage of the rapid development of computer architecture and software of the linear programming model. More minute and informative results can be obtained for policy proposals.

In Chap. 7, the dynamic interregional input–output programming model is shown, which is, however, a simple discrete linear model (not nonlinear). It looks like an extension of the DOSSO model, but the malleability of capital is completely denied (at least, it is not a sausage model); it is not focused on a steady-state rather on

the transitional phase of transforming the economy in order to reply to practical agendas. It is applied to the evaluation of Asian Expressway construction investment project as a strategic variable for the Chinese economy to take off.

We owe many people who have assisted us in copywriting and preparation of materials, some of which laid gathering dust for a long time in a stockroom. Without their devotion, this book would not have been completed at this time. Firstly, to be praised is secretary to Dr. Takeshi Mizunoya' study room (and, to former Higano's study room), Ms. Hatsumi Uchimura, who has contributed to make a fair copy of manuscripts. Sasaki Publishing Printing Co. Tokyo Branch Office Editorial Adviser, Mr. Tatsuya Shimatai, contributed by advising us on how to compose difficult troublesome graphs; to publishing editor, Mr. Yutaka Hirachi, and editorial staff, Ms. Misao Taguchi, we express our deep and sincere gratitude.

Tokyo, Japan — Hirotada Kohno
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1.1 Underlying Fundamental Concepts of Public Investment Criteria: Significance and Necessity

1.1.1 Definition of Investment Criteria

Under the scarce total capital fund that is given in advance by the capital rationing through, for example, policy arguments between the alternative sets of investment targets such as the projects of road construction administered by the ministry of construction, the projects of the railway by the ministry of transportation, the projects of research and developments by the ministry of education, science and technology, and so on, the most concern, for example, the ministry of construction, which is in charge of planning and implementation of the projects of road, is to choose a set of projects of road to which the limited fund may be assigned. The ministry or the department in the ministry has to make a kind of selection between projects and determine a certain set of projects in a consistent manner by considering the accountability because it may usually not include all the projects which the department may implement even if the allocated fund through the capital rationing to the department were huge. The *static* investment criteria work as a sort of *Merkmal* (an indicator) in the choice of the optimal set of projects consistently in the sense that the additional total social surplus (the sum of consumer and producer surpluses = social benefits), which can be created in the whole national economy owing to the implementation of the optimal set of projects, is greater or at least is not less than the social surplus that is to be created by implementing other sets of projects created through the selection subject to the limited fund.

The essence of the public investment criteria is that: (1) the optimal set of projects, (2) the scale of projects in the optimal set to which the fund is to be allocated, and (3) the timing of implementation of projects in the optimal set if, for example, the total capital fund is given as an annual stream of budgets, and so on, are endogenously solved and simultaneously determined. The adoption of the public

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investment criteria in this manner will make efficient the allocation of the limited fund to the chosen and implemented projects in terms of the opportunity cost of the capital funds. This is critically different from the basic benefit–cost analysis principle in which typically the amount of allocated fund is predetermined and the project selection is made external to the principle, its scale and timing of implementation and so on are predetermined, and whether the increase in the social benefits, thanks to the project selected in advance, deserves the fund or not is the main concern in the analysis irrespective of how the allocation of the fund, the choice of the project, and so on were predetermined. However, in reality, the case in which the conventional benefit–cost analysis is yet adopted rather usually and even such cases are almost all with the public project management. Significance and necessity of the adoption of the public investment criteria in public investment management and the related topics are first taken in this chapter.

To apply the public investment criteria to the allocation of the limited fund to a limited number of public projects, which shall be implemented after choice among a set of potential investment targets[1] on *a certain criterion*, with respect to *each* potential public investment target (it is a public project) in the choice set, the sum of the increase (or decrease, that has a negative value) in the producers' surplus (profits) and consumer's surplus in the markets (including newly created) of the whole national economy, or, at least, a certain scope of the economy that is to be affected by the public investments in the choice set, are to be estimated focusing on the shifts of demand and supply curves in all the markets directly and indirectly affected by the public investment. The estimation is made over *the time horizon* of the public project, which means the time span in which impacts of the public investment continue. Finally, the time series of the sum of increases/decreases in producers' and consumers' surpluses over the time horizon are capitalized in terms of the value at the beginning of the initial period using a certain discounting ratio. The capitalized value (or, we sometimes call it—discounted value) is called the *benefits* or *economic effects* of the public investment, and it is an indicator of the increase in the welfare of the whole national economy owing to the public investment. In the case where the limited fund is very small compared to the total investment in the macroeconomic sense, as it is a usual case, it may be taken as the marginal benefits of the marginal public investment as far as the chosen public projects are independent of each other, which means that the created benefits by the chosen public project are independent of whether one or some of the other chosen public projects are implemented or not.

The ratio of the benefits to the cost[2] that is required for the implementation of the public project is calculated with respect to each public investment target, and it works as a marginal benefit indicator of public investment. Using the indicator, the optimal allocation of the limited capital fund to potential public investments targets and, therefore, the optimal set of chosen public projects that shall be implemented

[1] The set of public investment targets is called—the choice set.

[2] In case in which costs are required over the time horizon, the series of costs are capitalized, too.

using the limited capital fund is pursued to maximize the total capitalized benefits that are to be generated by the chosen public projects (Nakamura 1970, pp. 34–37).

The calculation of benefits to obtain the marginal benefit indicator and the solution process of the maximization stated above constitute the theory of *static* investment criteria.[3] However, there could be variations related to the maximization process depending on: (1) whether the conventional benefit–cost ratio or benefit-less-cost indicator is applied to the maximization process; (2) whether all the marginal benefit indicators are applied *in a lump sum manner* to the selection of the set of potential (feasible) public projects that shall be implemented with the limited fund; (3) the method applied to the calculation of the benefits that are critical components of the marginal benefit indicator; (4) to what extent *indirect* economic effects shall be included in the benefits; and (5) the scope of the economy with which the benefits created by the public project are to be calculated, and so on (Oishi 1960; Sasaki et al. 1965; Kohno 1974).

1.1.2 Significance of Public Investment Criteria

In the case of the business with the public utilities (whether they explicitly or implicitly exist in the economy does not matter), which utilize large-scale social infrastructures that are usually constructed through the public investment(s), (1) the control of the quantity (e.g., the traffic volumes on the expressway) in the short run through the price (fare) adjustment and (2) the control of the public investment to increase the capacity of the social infrastructures and, thus, control the quantity, are inconsistent with each other in the laissez-faire market, and results are *not* socially optimal because the decreasing marginal cost and, therefore, what the marginal cost is less than the average cost while it is decreasing with quantities produced is the pertinent characteristic to the public utilities (Negishi 1964, pp. 29–31). This means that we should not rely on the market mechanism with the quantity and/or investment adjustments through the price mechanism. In this case, (a) the control of the capacity of the social infrastructures shall be made through the application of the public investment criteria presuming the full utilization of the capacity by rather adopting the marginal cost pricing than the self-supporting accounting system that would damage the optimal organization of social infrastructures and (b) a possible deficit by the adoption of the marginal cost pricing (because the marginal cost cannot

[3] Here, only the public investment criteria will be discussed. Of course, the theory and measurement investigated here can be applied to the *private* (enterprise) investment criteria, also. The main difference between the two is that the benefits with the public project is "social benefits – economic effects created in a certain scope of the economy, typically the whole national economy" and the benefits with the private project is replace by "revenues in the private sense – revenues which only accrue to the firm which makes the investment." The concept of social discount rate is inherent to the public investment criteria. With the private investment criteria, it is replaced by the interest rate in the market.

cover the average cost) shall be compensated by, for example, using the government general/specific budget. This dichotomy is the kernel of Hotelling Theory that the public investment should be dealt with in a unitary manner focusing on the relation between the maximized total surplus (benefits) that are created by the investment and its necessary costs, namely, the benefit–cost criteria (Hotelling 1938). Here is the significance of the public investment criteria.

1.1.3 Adjustments with Product Quantity and Investment Quantity

Generally speaking, the market plays an important role truly with the short-run adjustment of product quantity through the price mechanism, but with the long-run adjustment of investment quantity, especially the public investment or construction of public facilities (infrastructures), it does not well perform as expected. Here, we would forward our arguments by introducing the following concepts:

1. Allocation objective and revenue objective.
   There are two objectives related to public utility activities. One is *allocative objective* and the other is *revenue objective*. The allocative objective is to attain the optimality of resource allocation (e.g., optimal capital fund allocation in the long run, the optimal degree of the rate of utilization to the capacity in the short-run in which the capacity of social infrastructure is fixed, etc.) in the light of the objective function of society, for example, the social welfare function, the sum of the social surpluses, and so on. On the other hand, the revenue objective is the maximization of revenues even if the allocative objective was not attained in the long run or in the short run. In relation to these concepts, we need to mention the pricing theories that are applied to, for example, the toll and fare charged by the public utilities.
2. Marginal cost pricing principle and average cost pricing principle.
   The allocation objective is surely attained by charging toll or fare, in conformity with the marginal cost pricing principle, on the users (consumers) of the goods (e.g., tap water) /services (e.g., expressway services) provided by the public utility, although the revenue objective may not be attained. On the other hand, the dependence on the average cost pricing principle assures the attainment of the revenue objective, but the allocative objective becomes imperfect (Table 1.1). The investment by private companies is essentially different from public investment. The decision-making of the former is simple compared to the public investment criteria (and still it is a tough business for the executive officers in the company) in the sense that when they apply a feasibility study, for example, based on internal rate of return or cap rate, they fairly can place reliance on the direction of the market now or in the near future as far as they have the capability of management. The latter has to involve a kind of forecast or prediction of the direction of the market in the long run to obtain the public investment criteria. The

Table 1.1 Summary of discussion in Sect. 1.1

Control mechanism for industries which produce under decreasing marginal cost	Objective	Private company (supply curve (= marginal cost curve) is increasing with the quantity produced)	Public utility (supply curve is decreasing with quantity produced)
Nothing (the laissez faire market)	Optimality of the quantity produced in the short run	Attained	Not attained (e.g., due to natural monopoly)
	Revenue objective in the short-run	Attained and socially optimal	Attained and not socially optimal
	Optimality of the resource allocation in the short-run (optimal utilization of the fixed amount of facilities)	Attained	Not attained (e.g., same reason in the above)
	Optimality of the resource allocation (=investment) in the long-run	Not attained (owe to feasibility study based on internal rate of return/cap rate, etc.)	Not attained (owe to feasibility study based on the public investment criteria)
The marginal cost pricing (MCP) principle in a unitary manner	Optimality of the quantity produced in the short-run	–(n/a)	Attained
	Revenue objective in the short-run	–(n/a)	Attained but deficit
	Optimality of the resource allocation in the short-run (optimal utilization of the fixed amount of facilities)	–(n/a)	Attained but deficit
	Optimality of the resource allocation (=investment) in the long run	–(n/a)	Not attained (owe to feasibility study based on the public investment criteria combined with MCP principle)
Average cost pricing (ACP) principle in a unitary manner	Optimality of the quantity produced in the short run	–(n/a)	Attained but not socially optimal
	Revenue objective in the short-run	–(n/a)	Attained but not socially optimal
	Optimality of the resource allocation in the short run (optimal utilization of the fixed amount of facilities)	–(n/a)	Attained but not socially optimal
	Optimality of the resource allocation (=investment) in the long run	–(n/a)	Not attained as far as ACP principle is adopted even if the public investment criteria is applied