Allocation of Public Resources for Scientific Research : The Role of Governments and the Law

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Note

Allocation of Public Resources for Scientific Research: The Role of Governments and the Law

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Contents

Abstract

Over centuries, efficient allocation of limited resources has been one main concerns of governments and social scientists. The emergence of the Internet fuelled the proliferation of online matching platforms that facilitate the redistribution of omnipresent surplus resources. This paper examines the role of governments and the law in facilitating the most efficient allocation of public resources to academic researchers. Assuming that diversity of funded research projects is one of the primary goals, we developed a hypothetical social network

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model that helps us comparing two major policies employed by governments in allocating public funds ("selection and concentration" and "diverse allocation"). Our findings highlight the potential advantages of both funding approaches and illustrate that larger and more selective models could potentially lead to more diverse allocation of public resources. Accordingly, we offer some policy recommendations, one of which is that governments (and legal frameworks) should utilize multiple resource allocation approaches for such strategy could lead to more efficiency and diversity.

Ⅰ. Introduction[(1)]

We are quite often troubled by a lack of resources. For example, researchers of academic or research institutions often complain about limited financial resources. Similarly, entrepreneurs face difficulties in their access to investors and venture capital. In our daily lives, we may be often bothered by insufficient supply of transportation in urban, as well as local, areas. The supply of accommodation in popular tourist destinations cannot meet the quickly increasing demand from visitors.

However, from the perspective of society as a whole, such a problematic situation does not necessarily mean that there is a lack of resources. As always, there is surplus of resources somewhere in society, although many complain about a lack of resources. For example, several researchers and institutions enjoy a generous budget. A few limited "Unicorns" attract a large amount of venture capital investment. Most private cars transport "air" but

(1) This paper is based on the keynote speech of the same title made by Shinto Teramoto at the 8th International Conference on E-Education, E-Business, E-Management, E-Learning, Kuala Lumpur, Malaysia, January 5-7, 2017 (http://www.icglc.org/ks.html). We are grateful for the financial support we received from J-Mac System, Inc. (Sapporo, Japan), eSite Healthcare, Inc. (Tokyo, Japan), Linux Professional Institute – Japan (Tokyo, Japan), General Incorporated Association HAKUSEIKAI (Tokyo, Japan), and Japan Communications Inc. (Tokyo, Japan).

for their drivers. Apparently, our residences are often vacant when we go to work or school, or we go on vacation. Presumably, a lack of a diverse allocation of resources, rather than an insufficient supply of resources, would be the major cause of the problem.

Assuming that there are would-be beneficiaries of and potential demand for a more diverse allocation of resources, governments are expected to initiate and promote such an allocation. Lawyers and economists are expected to provide governments with theoretical grounds to show the benefit of a diverse allocation of resources, as well as the legal framework to initiate and/or promote a more diverse allocation of resources.

Our attempt in this paper is to assess the possible governmental role in initiating and/or promoting a more diverse allocation of resources by using a relatively simple social network model. Experiments on a simple network model, as well as empirical knowledge, suggest that there is a substantial probability that the input of resources to persons and entities having a good capability to reallocate those resources would facilitate a more diverse allocation of resources.

We start this paper by discussing the emergence of sharing economy business models which aim to reallocate surplus resources in a more efficient manner. Sharing economy businesses are technically based on online matching platforms that connect omnipresent surplus resources with the existing demand in the market. Then, we explain the existing situation in the allocation of public resources to scientific research projects in Japan and address the criticism of various governmental policies in allocating public funds for research purposes.

In Chapters II and III of this paper, we argue that "selection and concentration" policy potentially helps it to perform the function of matching. In particular, we submit that instead of allocating equal amounts of funding to many researchers, public funds can be selectively distributed to fewer but larger projects. Such "selection and concentration" approach could potentially lead to

a more efficient allocation of public resources and reach a more diverse group of researchers.

To support our claim, we developed a model which examines the changes that occur between relationships among researchers and the flow of funds over time. In Chapters Ⅳ and Ⅴ, we illustrate the flow of funds in two different scenarios ("selection and concentration" policy and diverse allocation policy). The results obtained from the studies based on the model seem to suggest that "selection and concentration" does not necessarily contradict to "diverse distribution of resources." Rather, the former possibly contributes to achieve the latter. Moreover, our study shows that, in the case of selection and concentration, funds are likely to be distributed to a more diverse circle of researchers.

Based on those findings, in Chapter Ⅵ, we offer insights for fund allocation policy in the future suggesting that governments should employ multiple fund allocation policies simultaneously. Such an approach of combining several fund allocation methods could likely increase the efficiency of utilization of public resources and contribute to the diversity of scientific research.

Ⅱ. The Role of Matching in Allocating Surplus Resources

A. Lack of Resources, or Lack of Matching?

We often complain about the lack of resources that we need. Also, our family members, friends and colleagues complain about a lack of resources. For example, travelers visiting metropolitan areas often complain that it is difficult to find reasonably priced accommodation. When we arrive at a local airport at night, we often feel disappointed to find that only one taxicab is available for passengers and the last bus to the main street has already gone.

However, viewed from a different perspective, small surpluses of all types of resources are omnipresent, but these surpluses, which when aggregated constitute a vast resource, are simply unused because they can not be matched with

demand. For example, as of the end of March 2015, the number of registered private passenger automobiles (excluding light automobiles (*Kei-jidōsha*)) in Japan was 39,255,000, while that of registered commercial use passenger automobiles (taxis, limousines, etc.) was 237,000 and that of buses was 111,000.[2] In contrast, the average annual mileage of private passenger automobiles in 2015 was 8,200 km, while that of passenger carriage automobiles was 28,500 km, which is more than three times that of the former.[3] Apparently, such a vast resource for passenger transportation which could have been provided by private passenger automobiles is unutilized.

Another example could be found in the usage of our homes. According to a survey conducted in 2015, the average amount of time that Japanese residents spend in their homes is only around 50% to 75% of the day.[4] When we are not at home, this accommodation capacity is just left unused.

The rise of so-called sharing economy platforms, such as Uber[5] (for the matching of passenger transportation and passengers) and Airbnb[6] (for the matching of accommodation resources and travelers), that attempt to match small but omnipresent resources and demands, make us suspect that the lack of resources is actually due to a lack of appropriate matching between surplus resources and demands.

B. Lack of Research Funding, or Lack of Matching?

Governments often insist that they have insufficient funds to allocate grants

(2) Ministry of Land, Infrastructure, Transport and Tourism (2016), Automobiles in Figures. (*Sūji de miru Jidōsha*), Automobile Business Association of Japan, at p. 2.

(3) Ministry of Land, Infrastructure, Transport and Tourism (2016). Safe Measures for Road Traffic (*Dōro kōtsū no anzen shisaku*), Reviews of the Policies (Assessment) in FY2015, p. 55, available at http://www.mlit.go.jp/common/001125128.pdf and http://www.mlit.go.jp/common/001125130.pdf (last accessed on 25 October 2017).

(4) NHK Broadcasting Culture Research Institute, Report of a survey carried out by NHK on how the nation's people use their time (*Kokumin seikatsu jikan chōsa hōkoku-sho*), 2016, available at https://www.nhk.or.jp/bunken/research/yoron/pdf/20160217_1.pdf, at p. 54 (last accessed on 25 October 2017).

(5) See https://www.uber.com (last accessed on 25 October 2017).

(6) See https://www.airbnb.com, and https://www.airbnb.jp (last accessed on 25 October 2017).

to every researcher who needs funding, and that, therefore, "selection and concentration" is inevitable in the allocation of research funding.[7] However, many academic researchers complain about scarce funding for their research.[8] Moreover, some of them argue that "selection and concentration" is the main cause of the financial difficulties faced by many research projects and that such fund allocation policy is likely to obstruct the progress of science. The critics of the "selection and concentration" approach in allocating research funding among researchers argue that it gives a limited number of researchers or research projects preferential treatment, while forcing the majority of researchers and research projects to suffer from a lack of funding.[9] Presumably, those critics deem that giving every researcher and research project equal access to funding would promote diversity of research and human resources.

However, the authors wonder if this argument is based on a myth or a misunderstanding. A possible disadvantage of allowing everyone to have equal access to funding could be insufficient funding for everyone. A possible benefit of "selected and concentrated" funding is the flow of sufficient funds from well-experienced researchers to multiple capable but young researchers and from big projects to multiple smaller-scale projects. For example, "ImPACT" (Impulsing Paradigm Change through Disruptive Technologies) Program of the Cabinet Office of the Government of Japan, which was launched in 2014 and is funding sixteen research projects as of the end of 2016, is a typical "selection and

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(7) For example, The 3rd Science and Technology Basic Plan (Cabinet Decision of March 28, 2006) of Japan (available at: http://www8.cao.go.jp/cstp/kihonkeikaku/honbun.pdf, last accessed on 25 October 2017) repeatedly emphasized the necessity to employ "selection and concentration" policy. See also public research policy trends outlined by OECD in its Science, Technology and Industry e-Outlook, available at: goo.gl/9rSZ5f (last accessed on 25 October 2017).

(8) See e.g. The Ministry of Education, Culture, Sports, Science and Technology, 2016, About a questionnaire survey of an individual research expense, available at: goo.gl/vF9D7K (last accessed on 25 October 2017), and Nikkan Kōgyō Shinbun (August 25, 2016). The academic funding allocated to individual researchers is reduced by 60 percent and is under 500,000 Yen through the year, p. 23.

(9) See e.g., Sankei Biz (2017), shows concerns of "Selection and Concentration" approach in academic funding ("Kagaku kenkyūhi sentaku to shūchū de ōyō jūshi, kiso ni shiwayose"), available at: goo.gl/GvD8vN (last accessed on 25 October 2017).

concentration" research funding program.[10] One of the research projects funded by ImPACT is the five-year research project "Actualize Energetic Life by Creating Brain Information Industries" managed by Mr. Yoshinori Yamakawa (hereinafter, the "Yamakawa Project").[11] The Yamakawa Project received funding of 3 billion Japanese Yen (over US$25 million) in total from ImPACT. Such a large fund size, as well as the limited number of projects of the same scale, implies that ImPACT follows "selection and concentration" approach. As outlined in Table 1, the Yamakawa Project is comprised of five sub-projects, each of which has different but mutually related purposes. In addition, each of the sub-projects is comprised of more than fifty research groups. Apparently, the Yamakawa Project has been successful in re-allocating a large amount of research funds among diversified research groups. In other words, the program manager, Mr. Yamakawa, has made successful efforts in matching research funds with different research groups.

Project 1	Brain Big Data	Kamiya	ATR
		Hara	Kyoto Univ.
		Abe	Kyoto Univ.
		Okanoya	Univ. of Tokyo
		Imoto	NIPS
		Kanai	Araya
		Aoki	Juntendo Univ.
		Murai	Kyoto Univ.
		Harada	Univ. of Tokyo
Project 2	Portable Brain Machine Interface	Yamashita	ATR
		Suyama	ATR
		Imamizu	ATR
		Inoue	Shimadzu

(10) See http://www.jst.go.jp/impact/en/index.html (last accessed on 25 October 2017).
(11) See http://www.jst.go.jp/impact/en/program/11.html (last accessed on 25 October 2017).

		Tanaka	ATR
		Takemoto	NTT
		Tanaka	Sekisui
		Kawanabe	ATR
		Matsushita	Gifu Univ.
		Kitashiro	Riken
		Sustain	Oita Univ.
		Mizuhara	Kyoto Univ.
Project 3	Brain Robotics	Ishiguro	Osaka Univ.
		Nishio	ATR
		Sumioka	ATR
		Yamasaki	ATR
		Morimoto	ATR
		Hirata	Osaka Univ.
		Nakae	Osaka Univ.
		Suzuki	NICT
		Yamamoto	NICT
		Osaka	Oita Univ.
		Hiraki	Univ. of Tokyo
Project 4	Open Brain Information Infrastructure	Watanabe	Riken
		Kobayashi	Shaman Univ.
		Sasaki	Iwate Medical Univ.
		Ida	Kyoto Univ.
		Pak	Kochi Univ. of Technology
		Nakae	Osaka Univ.
		Nishio	ATR
		Teramoto	Kyushu Univ.
Project 5	Applied Technology	Nemoto	Tsukuba Univ.
		Aramaki	Chukyo Univ.
		Made	Osaka Univ.
		Ikuta	Univ. of Tokyo
		Hattori	NPO Neurocreative

		Tamori	Kanazawa Institute of Technology
		Iriki	Riken
		Inui	NIPS
		Suzuki	Tokai Kogaku
		Takeuchi	Miyuki Giken
		Ono	Nippon Medical School

Table 1. Sub-projects of Yamakawa Project

In light of our experience concerning the lack of hotel accommodation or the lack of transportation means which are being solved by matching services such as Airbnb or Uber, as well as the possible reallocation of research funds by a program manager of a large research project funded by a government such as the Yamakawa Project, we may suspect that the lack of research funds is due to the lack of matching between funds and researchers or research projects, rather than the shortage of total funds available for the purpose of promoting academic research.

III. Promotion of Diversity by Means of Selection and Concentration

We do not have a crystal ball to predict whether and which research projects will make a positive impact on the society or future development of science. If we were to allocate funding only to those research projects that currently appear to be very practical and productive, it would undermine the number of possibly successful research projects and researchers. Considering our limited capability to predict the future, it would make more sense to allocate funding to more diversified research projects and researchers.

Assuming that diversity in funding is desirable, it might seem reasonable to allocate funding to as many research projects and researchers equally. How-

ever, this might be a hasty and irresponsible policy, especially if we consider various concerns. For instance, the amount of funding equally allocated to different research projects or researchers is likely to be too small for some of the projects and researchers, and too excessive for others. Furthermore, if we estimate the amount of funding required for different projects or researchers, and change the amount of the funding allocated to each of them, it means that we are employing, or at least combining, the policy of "selection and concentration." Moreover, as often found in the course of the application and allocation of so-called competitive research funding, considerable initial and continuing costs are involved in implementing such schemes. These costs include, but are not limited to, estimating the necessary fund size, as well as written research proposals, by the respective candidates of project managers and researchers; peer-review by the researchers of such estimates and proposals; and continuous review and/or auditing to prevent unfair or dishonest use of funds by researchers and to evaluate the product of the funded research projects.

In light of the experience from the Yamakawa Project, in which one of the authors (Teramoto) himself is participating as a member researcher, the authors suspect that fund allocation according to the policy of "selection and concentration" possibly reduces such expenditure at the same time maintaining funding to diversified projects and researchers. If research funds are allocated among research projects and researchers according to the policy of "selection and concentration," naturally, the number of candidates of the projects and researchers to which funding is possibly allocated will be limited. If only a limited number of researchers prepare the said estimates and research proposals, the total cost thereof is likely to be much less than the total cost when each of the numerous researchers have to prepare such documents. Moreover, assuming that only a limited number of researchers can employ staff skilled in such documentation, the difference between the cost is likely to become greater. In addition, the informal and mutual review between the participants of a

large-scale project can be more efficient in motivating the respective researchers to make their best efforts to produce the research outcome than the formal review or audit of numerous projects and researchers by governmental agencies or public institutes, with the added advantage that informal review involves little additional cost.

A large research project is likely to include multiple and diversified research projects and researchers with more diverse backgrounds. Also, the project manager of a large project is more likely to have a social network and direct connections with researchers from more diverse expertise. Under such probable conditions, the fund allocated to a large project is more likely to be re-allocated among diversified multiple sub-projects and researchers.

Nevertheless, the authors do not blindly support a "selection and concentration" policy in allocating research funds, because it possibly has its own problems. For instance, the social networks of respective project managers of large research projects can be heavily redundant. This is graphically visualised in Figure 1 below which shows a social network in which many of researchers connected with one project manager are also connected with other project managers and other researchers. In other words, many of the researchers solicited by the project manager A of one project can also be solicited by the project manager B of another project. In such a case, the funds of respective projects are likely to be misallocated to the same sub-groups or researchers and diversity in fund allocation will not be attained.

However, regardless of the risk of redundant ties, the foregoing discussion suggests the possibility that "selection and concentration" approach in allocating research funding could promote diversity of research projects and researchers.

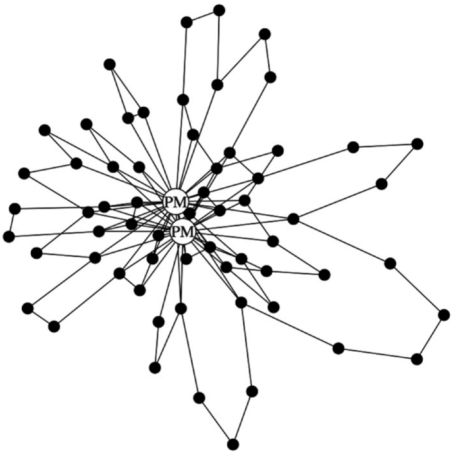

Figure 1. This graph shows how the social networks of two project managers (PM) are heavily redundant.

Ⅳ. Discussion Using Network Model

A. The Purpose of the Model

"Selection and concentration" approach in allocating research funds could be beneficial for its potential to promote diversity of research projects. Yet, much information and time are required in order to support this claim with actual data. Therefore, before sufficient data is collected, the authors have developed a simplified network model (hereinafter, the "Model") which helps us explain that allocation of research funds based on "selection and concentration" approach potentially leads to greater diversity in research projects. At the same time, it is important to note that the proposed Model cannot represent the real society as it is, because the variables of the Model represent only limited features chosen to design the Model ignoring some of the other features that may come into play. In addition, there is no guarantee that each variable adequately represents such features. Therefore, one should not hastily con-

clude that the said suggestion is totally justifiable, even though such discussion could be helpful to consider possible ways to design a useful policy for research fund allocation.

B. The Design of the Model

In order to ensure that the Model represents the multiplicity of researchers, each of whom has different extensions of his/her social network, the development of the social network in the Model is designed to start with a random graph. Thus, Figure 2 depicts an example of a random graph comprising 64 nodes, in which the probability that a tie exists between any pair of nodes is 0.05.

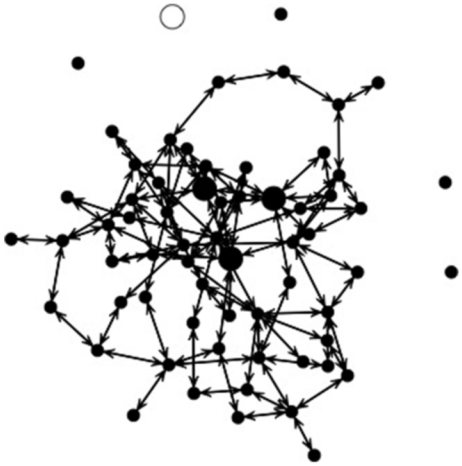

Figure 2. An example of a random graph with 64 nodes

1. Default Conditions of the Model

In order to represent the allocation of research funding by the government or a public entity to research projects and researchers, the Model has to contain one or more nodes denoting such source of funding. For the purpose of simplicity and convenience, the Model assumes that the number of such source of

funding is one. Also, the Model assumes that such source has no or little bias in its social connection with researchers. In a graph which denotes a social network, a node which has no or little ties with other nodes can denote such source in a very simple manner. In the Model, a node which has minimum eigenvector centrality[(12)] is chosen to denote such source of funding (hereinafter, such node is referred to as the "Source"). If there are multiple nodes having minimum eigenvector centrality, one node is chosen from among such nodes arbitrarily. Even though it depends on the conditions of the default network of the Model, it is likely that such a node is an isolated one, that is a node that has no connection with other nodes.

Some of the researchers have stronger and denser social networks with their peers, while others relatively weaker and sparser social networks. In the Model, the nodes having higher eigenvector centrality in the default conditions of the Model denote the researchers having stronger social networks, while the nodes having lower eigenvector centrality in the default conditions of the Model denote the researchers having weaker social networks.

The authors intend to introduce a Model to denote the flow of funding from the Source to researchers and the re-allocation of such funding among researchers. The flow of funding from the Source to each of the researchers can be denoted by an arc (*i.e.,* a directed tie) sent by the Source to the node denoting such a researcher. Likewise, the flow of funding from a researcher to another researcher can be denoted by an arc sent by the node denoting the former to the node denoting the latter. However, if such arcs denoting the flow

(12) See e.g., P. Bonacich, "Power and Centrality: A Family of Measures", American Journal of Sociology, 92:5 (1987) pp. 1170–1182. In social network analysis, eigenvector centrality is a measure that denotes the influence of a node in a network. Assuming that a given undirected graph G has n number of nodes:
A is the adjacency matrix of G;
a_{ij} is an element of A; and
λ (lambda) is the maximum eigenvalue of A,
$C_{ev}(i)$, the eigenvector centrality of node i, is calculated as follows:

$$C_{ev}(i)=\frac{1}{\lambda}\sum_{j=1}^{n}a_{ij}C_{ev}(j)_{ij}$$

of funding are simply added to the random graph that denotes the default conditions of the Model, it becomes very difficult to distinguish the flow of funding from the original social networks among the researchers. In order to avoid such a problem, the authors prepared a series of graphs that show only the arcs denoting the flow of funding. Assuming that no researcher has been funded from the Source, and accordingly no allocation of funding is made between the researchers, the first one of such series of graphs shows only 64 nodes isolated from one another (Figure 3). The flow of initial funding from the Source to several researchers and re-distribution of such funding among researchers, which are denoted by an increasing number of arcs being sent and received among nodes, develop a network among these 64 nodes.

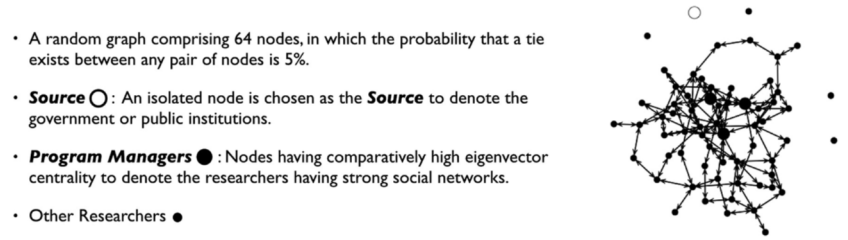

Figure 3. An example of the default conditions of the social network of researchers and the Source

The authors prepared two scenarios to develop the said Model. The first scenario denotes the allocation of research funding by the Source according to the policy of "selection and concentration" (hereinafter, "Scenario-c"). The second scenario denotes a more diverse allocation of research funding by the Source (hereinafter, "Scenario-d"). The authors intend to make Scenario-d depict the currently prevailing practice of the so-called competitive research funding, which combines equal allocation and selection and concentration halfway, as pointed out in Chapter III, above.

2．Scenario-c

Scenario-c is comprised of six instances. In the first instance, in order to illustrate the allocation of research funding to a very limited number of research projects or researchers, the Source sends arcs to only three nodes (hereinafter, the "Program Managers"). In order to denote the limited number of researchers having very strong and dense social networks who are likely to be nominated as program managers under the policy of "selection and concentration", the three nodes having top three eigenvector centrality in the default condition of the Model were nominated as the Program Managers.

In the second instance, in order to denote the redistribution of research funding by each of the Program Managers to other researchers, each of the Program Managers sends arcs to other nodes (except for the Source). Undoubtedly, a researcher who receives funding from the government or a public institution is not likely to redistribute the funds equally to each of the other researchers. Rather, he/she is likely to redistribute such funds to those researchers who already have a strong social linkage with him/herself. In order to implement this probable situation in the Model, the authors assume that the shorter distance[(13)] between a pair of researchers increases the probability that redistribution of funds occurs between them, and where such distance is longer, such probability gradually decreases. In order to implement the said relationship between the probability of redistribution of funding and distance between a pair of researchers in a simple and convenient manner, the authors employed the concept of a time constant (τ) as follows:

> $\boldsymbol{t}$: the distance from *node j*, which denotes a researcher who possibly receives redistribution of research funds, to reach *node i*, which denotes a researcher who possibly redistributes research funds.

(13) Distance has been defined as "the length of the shortest path via the edges or binary connections between the nodes." See Ch. Kadushin, *Understanding Social Networks* (OUP, 2012) at p. 33.

$\tau(=1)$: a variable that is greater than zero.

$P=exp(-t/\tau)$: the probability that *node i* sends an arc to *node j*.

On several occasions, a Program Manager may nominate researchers to whom research funding is redistributed. Also, a researcher funded by a Program Manager may redistribute funds to other researchers, who, in turn, may further redistribute funds to other researchers. Such redistribution is also made on several occasions. Moreover, it is possible that a researcher, who has already been funded, will receive a redistribution of funding from the same or different researchers.

The third through sixth instances are designed to denote such situation. In the Model, a node to which the Source is reachable through a path (*i.e.,* an arc or a series of arcs of the same direction) represents a researcher who received funding from the government directly or indirectly through one or more researchers. So, in each of these instances, a node, which can be reached from the Source, sends arcs to other nodes (except for the Source itself) at the probability of $P=exp(-t/\tau)$, as defined above.

3 . Scenario-d

Scenario-d is also comprised of six instances. In the first instance, in order to model considerably diverse allocation of research funding, the Source sends arcs to seven nodes, which are also referred to as the "Program Managers." The seven nodes having top seven eigenvector centrality in the default conditions of the Model were nominated as the Program Managers. The proceeds of the first through sixth instances also accord the setting of the Scenario-c.

C . The Development of the Network in the Model

The development of the network in the Model is shown in Table 2. The authors are interested in determining how the number of researchers who do not

receive research funding from the government or public institution can be reduced. The reduction of such nodes (hereinafter, "unfunded nodes") is also shown in Table 2.

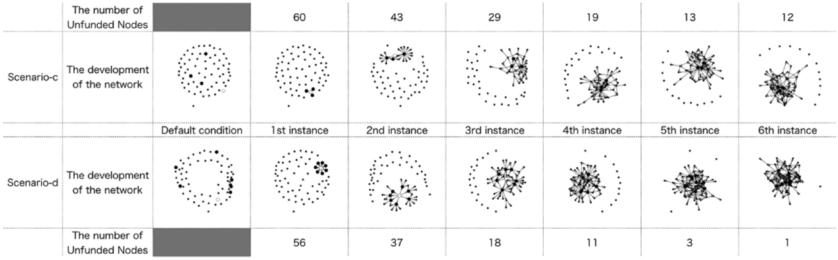

Table 2. The development of the network in the Model

According to the results shown in Table 2 above, the number of unfunded nodes of the Model employing Scenario-c (selection and concentration approach) is naturally greater than that of the Model employing Scenario-d. However, in practice, the research fund size initially allocated from the government or public institution to each of the project managers according to the policy of "selection and concentration" is likely to be much greater than that of more diverse allocation. Therefore, it is probable that the reallocation of research funds in Scenario-c is much greater than that in Scenario-d. Accordingly, in the real world, the remaining number of unfunded nodes in Scenario-c can be rival with or even smaller than that in Scenario-d.

Also, in the Model, just for the purpose of simplicity, every Program Manager is deemed to have the same degree of capability to send arcs to other nodes. However, in the real world, the Program Managers in Scenario-c are likely to have much stronger social networks compared with most of the Program Managers in Scenario-d. Therefore, presumably, the Program Managers in Scenario-c are likely to have stronger capability to send arcs to other nodes,

compared with most of the Program Managers in Scenario-d. In the real world, this is also likely to make the remaining number of unfunded researchers when selection and concentration model is used much smaller than that in the case of diverse allocation of funds.

V. Discussion Using a Data Set

A. Preparation of a Data Set

1. The Initial Data Set

In order to consider the viability of the policy of "selection and concentration" for the allocation of research funding, we have to observe the real world in order to confirm whether the assumptions of the said model are also found in the real world. As the first step of such observation, the authors examined the correlation between the strength of the social networks of the individual researchers and the research funding allocated to them by the government or public institutions.

Initially, the authors obtained the data from AiRIMaQ (Academic Research and Industrial Collaboration Management Office of Kyushu University[14]) concerning researchers who belong to Kyushu University and to whom research funding was allocated from governmental agencies or incorporated administrative agencies of Japan during the academic years of 2013, 2014 or 2015 by means of contract research[15]. Each of such contracts was executed between the relevant governmental agencies or incorporated administrative agencies of Japan and Kyushu University, while a specific researcher or researchers belonging to Kyushu University were nominated as program manager(s) to proceed with the research project specified in the contract. The allocation of subsidies was not

(14) See https://airimaq.kyushu-u.ac.jp/en/index.php (last accessed on 25 October 2017).
(15) The Japanese academic year begins on April 1st and ends on March 31st of the following year.

included in the initial data set.　The initial data set consisted of 306 researchers (including the author, Prof. Teramoto himself) of Kyushu University.

Also, for each of the researchers, the initial data set shows the number of contracts that nominated him/her as program manager, and the amount of research funding allocated to each researcher.　Japanese public research contracts, which nominate multiple researchers as program managers, usually determine the amount of research funding to be allocated to each program manager for each academic year.　Accordingly, in the initial data set, the amount of research funding allocated to each researcher is not necessarily the total amount of research funding on a specific project.　Rather, it represents the funding allocated to a specific researcher for a specific academic year.

2．The Data Set Derived by "Snowballing" the Initial Data Set

The initial data set consists only of program managers, but it does not include information on those who belong to the social network of each of those program managers.　In order to collect such information by using so-called "snowballing," the initial data set must be extended to include the researchers who have a relationship with one or more of the said program managers.

There are several means of finding such information.　For example, it could be possible to directly inquire each project manager with whom he/she is conducting joint research.　Alternatively, it could be possible to scrutinize co-authors of their academic works such as articles, papers, reports, presentations, books or the joint inventors named in patent applications.

It would be better to combine the social network information derived from multiple sources.　However, for the purpose of convenience, the authors tentatively looked up the joint research relationship for each research project using the Japanese public competitive research fund shown in a commercial database "Nihon-no-Kenkyū dot com"[(16)] that started during and after 2013.　Of course, there is no guarantee that such data is exhaustive or accurate.

After the said snowballing, the extended data set consists of 3,066 researchers, 306 of whom are the program managers contained in the initial data set, 308 of researchers are their joint researchers belonging to Kyushu University, and the remaining 2,452 are their joint researchers not belonging to Kyushu University.

B. Analysis of the Data Set

1. The Data Set in the Form of a Matrix

The data set extended by the said snowballing represents the joint-research relationship between each of the initial 306 program managers and other researchers. It includes the joint-research between researchers who are also included among the 306 program managers. However, it does not include the joint-research between researchers who are not included among the 306 program managers. The data set is formatted as a 3,066 x 3,066 square matrix, where each of the rows and each of the columns corresponds to one specific researcher. Also, the researchers are aligned in rows and columns in the same order. If researcher i and researcher j conduct joint research, the cell on which the row of i meets the column of j and the cell on which the row of j meets the column of i show the value 1. Otherwise, every cell shows a value of 0. For the purpose of simplicity, even if researcher i and researcher j conduct two or more joint research projects, the value is still 1.

2. The Data Set in the Form of a Network Graph

This 3,066 x 3,066 square matrix can be transformed into a network graph comprised of 3,066 nodes and edges denoting the relationship between the respective pairs of nodes (Figure 4 below). This graph gives us several intuitive presumptions such as:

- each of the researchers has his/her own social network of various

(16) See https://research-er.jp.

extension.　Some have very wide social networks, while others do not;

- direct relationships between a pair of researchers, both of whom have wide social networks, are found here and there;
- the majority of the researchers are connected with each other, directly or indirectly; and
- however, some of the researchers do not belong to such wider network, and only belong to very small social networks.

Figure 4. The network graph derived from our data set

3．The Correlation Between the Centrality of a Researcher and the Amount of the Allocated Research Funding

Next, the authors calculated the "degree centrality" and "eigenvector centrality" of each node contained in the said social network, which is denoted by the said 3,066 x 3,066 matrix and the network graph having 3,066 nodes. Then, the authors ranked the 306 program managers included in the initial data from largest to smallest depending on their respective "degree centrality." Likewise, the authors organized ranking using "eigenvector centrality."　The

authors also ranked the same 306 program managers from largest to smallest according to their respective total research funding from 2013 through 2015, as it appeared in the initial data set.

The left graph of Figure 5 is the scattering diagram showing the correlation between the ranking of degree centrality and the ranking of total research funding. Pearson's correlation coefficient between these two types of ranking was 0.578. The right graph of Figure 5 is the scattering diagram showing the correlation between the ranking of eigenvector centrality and the ranking of total research funding. Pearson's correlation coefficient between these two types of ranking was 0.558.

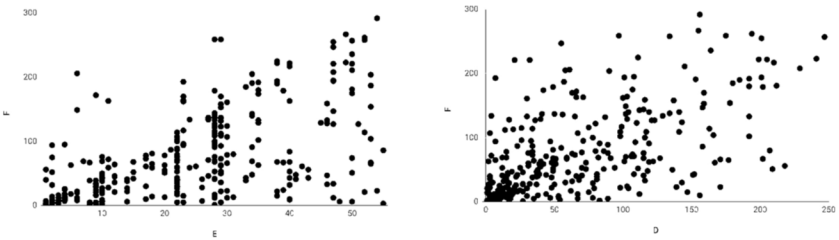

Figure 5. The scattering diagrams showing the correlation between degree centrality and total research funding (left) and correlation between eigenvector centrality and total research funding (right)

The data sets depicted in Figure 5 do not contain exhaustive data. Moreover, the authors' analysis to date is very rough. Hence, it would be too hasty to conclude anything. Nevertheless, Figure 5 lets authors suppose that the strength or extension of a researcher's social network has a weak correlation with the amount of research funding allocated to him/her.

Ⅵ. Suggestions Derived from the Discussion

The debates over the choice of policy for resource allocation have been almost entirely based on intuition or even emotion. Therefore, the pros and cons of "selection and concentration" or "diverse allocation" approaches remain open to the debate. However, the discussion using a simple network model and data-set, which, although subject to many limitations concerning the quantity and quality of data and primitive methodology of analysis, leads to two remarkable insights. First, the allocation of research funding according to the policy of "selection and concentration" is able to reach very diverse researchers by means of the strong social networks of program managers and reallocation of funds. Second, the number of researchers that have little access to such reallocation of funds is not negligible. In other words, researchers who have weaker ties to other researchers are less likely to become members of large projects and benefit from the reallocation of funds from managers of large research projects.

This analysis which we conducted in this paper suggests that both of the policies of "selection and concentration" and "diverse allocation" are justifiable under specific, yet diverse, conditions. Therefore, in allocating research funds, governments should aim to employ both "selection and concentration" as well as "diverse allocation" fund allocation methods. Combined application of those two research fund allocation policies could potentially increase the possibility of diversifying the range of researchers who are able to access public funding.

In light of this consideration, the law and governments can play several roles. For example, from the perspective of promoting the policy of "selection and concentration," in addition to the establishment of funding for big research projects as already made by governments, governments could enact laws that enable various types of preferential treatment to be given to industries, investors and taxpayers when they contribute or invest money to help such big projects. Also, governments could help researchers to extend their social networks by

allocating funds for social intercourse, attendance at conferences, and so on.

From the perspective of promoting the policy of "diverse allocation", equal access by researchers to a minimum amount of research funding should be guaranteed. It is also highly recommended to offer financial aid to researchers that are socially isolated thus helping to pave the way in building their social networks.