Cultivating Research Talent through Publicly-Funded R&D Program

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Abstract-**This paper is to utilize a fully integrated database about university researches in Taiwan and then analyze the collaboration patterns of commissioned projects granted by National Science Council. The contours of collaboration styles in knowledge diffusion among the scholars would also be sketched.**

I. INTRODUCTION

As we face the global competition for skilled human capital, countries that are able to attract or cultivate more skilled workforce will have comparative advantage. The quality and quantity of R&D personnel are key indicators for assessing the capacity of research and innovation of a country. For catching-up economies, publicly-funded R&D programmed is deemed as the main financial source and important mechanism for the cultivation of research talent. National Science Council (NSC) in Taiwan is the highest government body responsible for promoting Sci-tech development, supporting academic research and developing science parks. It is the main funding agency for academic scholars with the scale of fund reaching USD 190 million in 2008. Most universities are relying on NSC fund to provide financial support to scholars. Gaining NSC research grant is also critical for scholars to move up their career ladders. The NSC R&D programme was of strategic importance for both research institutions and performers. This study investigates R&D Programmes commisioned between 1991-2005 by the NSC in Taiwan. Using Reseachers Database constructed by the Council as the empirical base, this study aimes to analyze the portfolio and performance of participating scholars. As collaboration among national researchers is crucial for the knowledge diffusion, this study also analyses networking relationships among researchers and the impact of public-funded R&D programme on the revealed characteristics.

II. LITERATURE REVIEW

There are many researches discussing the performance of different academic areas. Moreover, in Humanities & Arts fields, some of the indicators in natural scienes are not suitable for use [1]. In order to discuss research talent cultivating, literature review about other researches to see if some objective evaluation indicators is important.

Table I. showes that many of Taiwanese researches talking about scholars' performance by

TABLE I

RELATED RESEARCHES FOR PERFORMANCE EVALUATION

Unit	Objective	Data source	Indicators
RSSS, Australia(2000)	Evaluating performance in education field of 38 research institutes and universities in Australia	REPP (ISI - based Au National Data Base)	Papers; papers/fund; papers/researchers; % of collaborations; Citation per paper; etc.
Prof. Cao, Taiwan.	Discussing performance in Economic fields of 22 similar universities in Taiwan	EconLit (1995-2000)	Quantity: papers, anerage papers per year; etc. Quality: Basing on the journal tiers to calculate researchers' points.
Prof. Wu, Taiwan	Evaluating the performance of scholars who applied project to NSC in 2000.	SSCI, TSSCI, conference papers, books.	Papers; Efficiency analysis in IO; etc.
Prof. Chen, Taiwan	Discussing 16 scholars' performance in psychology	SCI 、SSCI 、TSSCI (1996-2000)	papers/year;

referring to ISI database. They all based on paper published which didn't take the input information into consideration. However, due to different characteristics of academic fields, paper published patterens are quite diverse [2][3]. Only after analyzing each scholar's background information and his/her habitual behavior can we evaluate the performance. Besides, papers could be counted into one output from doing commissioned projects or programs by NSC. However, papers are not the only results. Whether the programs or projects form a research commity through personal academic network is also an issue for us to explore.

III. Methodology

This study adopts bibliometrics method and social network analysis for the understanding of the structure, research output and collaboration network of Taiwanese scholars. During the period of 1991-2005, there were 179,293 research projects commissioned by the NSC. A total of 23,791 researchere were involved in those project, accounting for 60 percent of all researchers working in the academic sector. Scholars are grouped into by 20 research categories, which were based on the classification of academic departments produced by the Ministry of Education. Scholars' specialties are defined on the ground of 128 sub-categories which are created from those 20 research fields. Papers published in the international journals are considered as the base for creating performance indicators. The output data was retrieved from ISI-Thomson database with over 8,500 journals covering 250 disciplines. Special indicators such as CPP (Citation per paper) by years, CPP by project experience, extent of collaboration and so forth are developed for detailed discussion. Both the portfolio and the output of participating scholars were thus analyzed according to the predefined research fields and indicators. Last but not least, this study uses network analysis to demonstrate the pattern of research collaboration. An automatic tool (PAJAK software) is used to handle large volume of data and to help the visualization of research networks for interpretation. Through these maps we assess whether the NSC funding programme is able to form richer, more diverse research networks that join scientists from different research fields.

IV. Results

This study touches some issues in cultivating research talent. We classify those issues in three dimensions. First is the capital investment. Cross analyzing investent funding data through different discipline and different research area, we realize the trend of capital investment of Taiwanese scientific development. We break down this part into two segments. The observation indicator for the first segmant is the scale for overall inverstment. As shown in Fig. 1, From 1991 to 2005, the average NSC commissioned fund was slowly increasing year by year. To sum, the academic fund has a steady 10+5% increments from 1991 to 2005. It is also found in fig. 2 that average research fund per capita was slightly increased in recent years. The unusually high for year 2000 was because of the different counting way. That period was counted for one and half fiscal year. The average project fund per capita has the same situation but with a more smooth rate, as shown in fig.3.

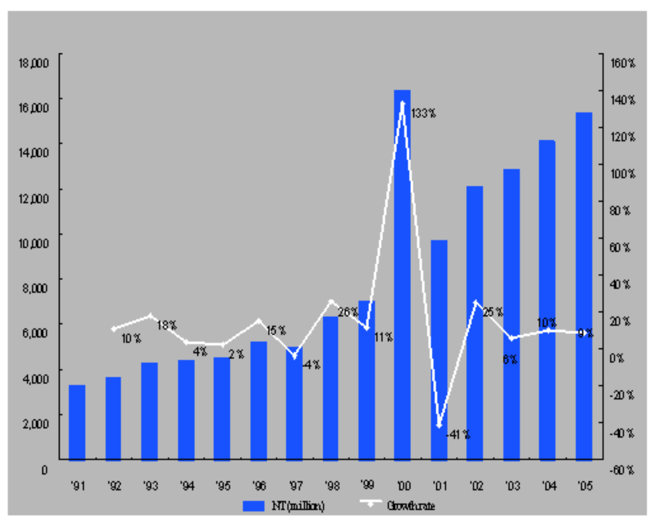

Fig.1. Growth trend of NSC commissioned fund by year

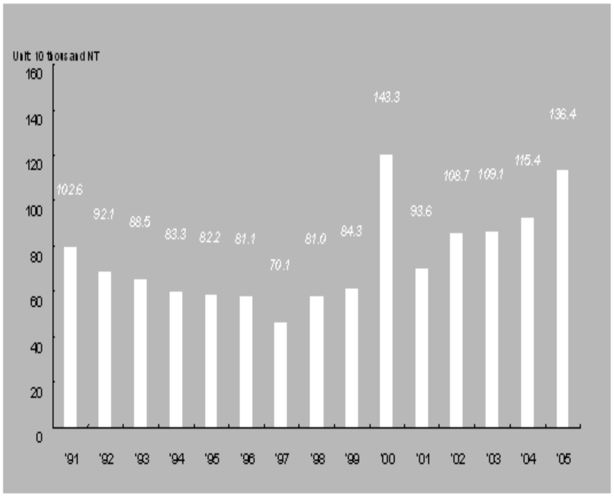

Fig.2. Average research fund per capita by year

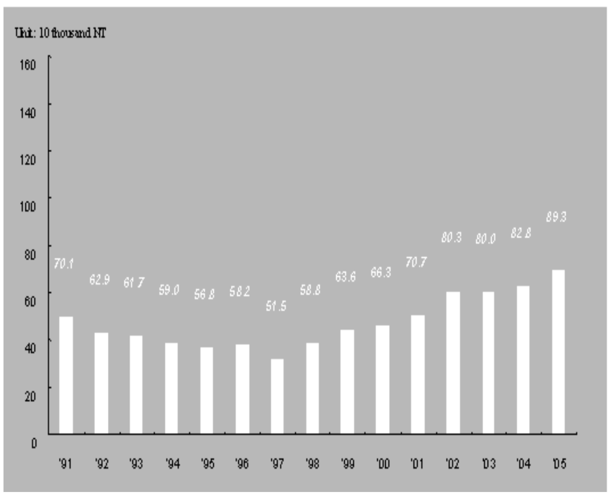

Fig.3. average project fund received per capita by year

However, when we look deep into the second segment of NSC funding distribution, it is found through table II. that the distributions of investments for NSC were quite skew. NSC invested mainly of its fund (88.3%) in seven major fields: engineering, natural science, and medical science, math & computing, Agri, forestry, fishery & livestock industry, management, and sociology & psychologywhere as 77.6% of the scholars (18,461/23,791) were supported. It is clear that research in sciences and engineering were emphasized more than art and humanities. 70% of the total funds were invested in engineering, natural science, and medical science which contain 50% of the researchers. Although NSC has set many different project scopes to fund, it still mainly focuses on first

TABLE II

FUNDING AND RESEARCHERS POPULATION BY FIELDS ('91-'05)

20 research fields	total investment	% of investment	No. of scholars	% of scholars	Ave. funding per capita
Engineering	37250	30.05%	5557	24.60%	6.7
Natural science	27037	21.81%	3578	15.80%	7.6
Medical science	21645	17.48%	2254	10.00%	9.6
Math & Computing	8201	6.61%	1900	8.40%	4.3
Agri, forestry, fishery & livestock ind.	5952	4.80%	1792	7.90%	3.3
Management	5376	4.34%	1380	6.10%	3.9
Social & psychology	4005	3.23%	1095	4.80%	3.7
Others	3733	3.01%	1065	4.70%	3.5
Education	3001	2.42%	1032	4.60%	0.9
Humanities	2378	1.92%	915	4.00%	2.6
Architecture & City planning	982	0.79%	401	1.80%	2.4
General knowledge	905	0.73%	325	1.40%	2.8
Housecraft	747	0.60%	283	1.30%	2.6
Transportation & Telecommunication	613	0.49%	205	0.90%	3
Sports	540	0.44%	193	0.90%	2.8
Law	520	0.42%	187	0.80%	2.8
Arts	446	0.36%	185	0.80%	2.4
Mass communication	443	0.36%	173	0.80%	2.6
Tourism	130	0.11%	61	0.30%	2.1
Craft technology	46	0.04%	13	0.10%	3.5

seven research fields.

Now we turn to NSC's organization structure to see its funding distribution. There are 5 departments in charge of research funding in NSC. They are Department of Engineering and Applied Science (Dept. of EA), Department of Humanities and Social Science (Dept. of HS), Department of Life Science (Dept. of LS), Department of Natural Science (Dept. of NS), and Department of Science Education (Dept. of SE). NSC still has other departments which deal with accounting, planning, and administrative business. From fig. 4., we notice that except EA, the funding allocations of each department remain the same proportions during these 15 years. Moreover, due to each department's mission and specialty, the main funding area was quite different from table III.

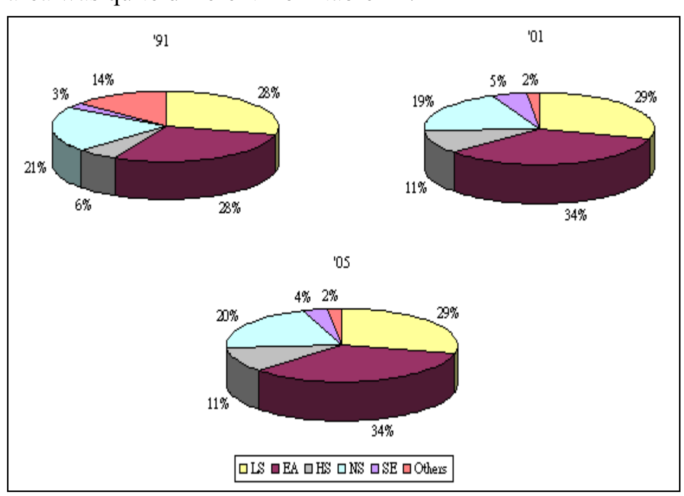

Fig. 4. Funding allocation for each dept. in NSC ('91/'01/'05)

TABLE III

FUNDING AND RESEARCHERS ALLOCATION FOR EACH DEPT. ('91-'05)

20 Research fields	Dept. of LS		Dept. of ES		Dept. of HS		Dept. of NS		Dept. of SE	
	$ Mount (million)	No. of Researchers	$ Mount (million)	No. of Researchers	$ Mount (million)	No. of Researchers	$ Mount (million)	No. of Researchers	$ Mount (million)	No. of Researchers
sociology & psychology	172.36	22	212.98	48	3149.71	1462	172.02	49	186.98	88
Management	573.71	106	810.87	621	2959.73	2210	779.75	320	170.6	115
Humanities	11.97	13	74.53	26	2189.11	1568	5.58	7	72.1	57
Education	92.71	48	129.1	97	1230.04	965	78.52	75	1456.73	586
Math & Computing	167.02	63	4623.3	1973	677.34	532	1967.93	733	581.68	304
Law	40.3	7	26.28	13	439.07	329	1.91	1	2.22	3
Medical science	18711.65	4683	1240.96	538	397.93	277	711.23	201	281.32	166
Mass communication	5.82	7	47.52	46	345.62	227	2.17	4	29.43	26
General knowledge	137.11	78	124.81	77	332.86	388	136.37	100	157.29	137
Engineering	993.61	385	30777.89	9082	324.14	240	2844.29	519	693.84	548
Sports	42.72	36	61.65	52	322.49	274	87	50	13.99	20
Others	1750.78	747	804.71	309	251.99	223	629.91	186	170.38	141
Arts	24.27	14	90.77	67	243.91	196	27.33	8	22.52	27
Architecture & City planning	22.53	15	697.42	367	225.67	149	0.48	1	17.82	25
Agriculture, forestry, fishery & livestock ind.	5125.43	1144	351.8	199	163.13	77	231.61	52	64.32	27
Transportation & Telecommunication	0.9	1	462.77	235	125.15	94	5.96	5	8.66	10
Housecraft	488.24	200	79.17	56	95.33	101	47.38	29	32.01	28
Natural science	7287.9	1306	1210.5	439	82.83	56	17451.67	1860	548.96	187
Tourism	32.73	23	11.51	19	65.44	76	0.32	1	19.77	18
Craft technology	0.54	1	39.91	38						
Total	35681.11	8932	41878.5	14302	13621.51	9444	25181.42	4201	4530.61	2513

Dept. of EA subsidized most funds to the researchers from 1991 to 2005, which mainly focuses on Engineering, Math & computing, and Medical science. Referring to each scholar's receiving funding, we find that in Medical science area, each scholar accumulates the most average research funding, which is 9.7 million, in these 15 years. The later would be Natural science are and Engineering area, which 7.6 million and 6.7 million individually. Researchers in medical science only took 10% part of whole researcher population who applied for NSC projects and were accepted. However, they received three times the funds than others, whereas funds of Natural science and Engineering are double than those of other research areas. It seems that Medical science, Natural science, and Engineering are still the focal areas for NSC to nurture talents. We break down the 20 main areas to 128 sub fields to see how the funding pattern goes. Table IV. Showed the top 15 sub-fields that NSC funded in. 50% of the resources were invested in 7 sub-fields, such as Medicine, EE, Biology, and so forth.

TABLE IV

TOP 15 ALLOCATIONS OF RESEARCH FUNDS IN SUB-FIELDS ('91-'05)

Top 15 sub-fields	Total amount (million)	%
Meicine	138.6	11.50%
Electron & electric machinery	129.3	10.70%
Biology	73.7	6.10%
Physics	71.86	5.90%
Mechanical engineering	71.37	5.90%
Chemistry	69.59	5.80%
Computer science	60.9	5.00%
Chemical engineering	37.4	3.10%
Others	36.07	3.00%
Material engineering	33.93	2.80%
Geology	26.48	2.20%
Business administration	23.43	1.90%
Multi-discipline in medical science	21.12	1.70%
Environment engineering	20.79	1.70%
Civil engineering	19.26	1.70%

Table V. takes our sight into another aspect. It classified research funds into different program/ (project) attributes. Most of the commissioned projects/programs place emphases on Engineering, Natural science, and Medical science. We can say that due to the total amount of researchers in these fields, more commissioned projects/programs were approved in these fields. When we refer to the accumulated average grants of researchers gained from commissioned projects in these 15 years in table VI, we find that in Engineering, Medical science, Natural science, and Agriculture, forestry, fishery & livestock industry fields, researchers received more funds from NSC than in other fields. That is to say, not only the more commissioned projects were approved by NSC, but also the more grants would be given to the researchers. To conclude, during 1991 to 2005, NSC commissioned more projects year by year in medical science and natural science, whether the departments of NSC are not with the same functions. Researchers tended to apply more projects in these fields, too. NSC did guide basic S&T development in Taiwan like this way.

TABLE V

GRANT DISTRIBUTIONS OF PROJECTS BY ATTRIBUTES ('91-'05)

20 research area	General research project		Specialty research project		National Defense research program		National S&T research program		Industry promotion & humancapital murturing program		Fresh researchers supported project	
	Total amount (million)	%	Total amount (million)	%	Total amount (million)	%	Total amount (million)	%	Total amount (million)	%	Total amount (million)	%
Humanities	19.10	2.10%	0.35	1.62%	0.04	0.31%	0.76	0.98%	0.02	0.17%	3.39	2.60%
Mass communication	2.94	0.32%			0.03	0.23%	0.49	0.63%	0.04	0.28%	0.85	0.65%
Engineering	263.81	29.04%	5.68	26.61%	7.31	60.68%	21.56	27.74%	10.51	71.56%	33.05	25.32%
Craft technology	0.16	0.02%							0.04	0.28%	0.18	0.14%
Natural science	200.73	22.10%	6.56	32.18%	1.99	16.50%	19.36	24.91%	0.71	4.85%	23.20	17.77%
Others	32.98	3.63%	0.26	1.20%	0.30	2.51%	0.79	1.01%	0.05	0.34%	2.02	1.55%
Law	3.88	0.43%			0.01	0.05%	0.41	0.53%	0.03	0.19%	0.81	0.62%
Architecture & City planning	7.63	0.84%	0.12	0.58%	0.00	0.04%	0.38	0.49%	0.22	1.52%	1.34	1.02%
Sports	4.10	0.45%			0.06	0.53%	0.06	0.08%	0.07	0.46%	1.00	0.77%
Housecraft	4.98	0.55%	0.20	0.95%	0.02	0.13%	0.18	0.23%	0.12	0.83%	1.70	1.30%
Management	40.00	4.40%	0.36	1.67%	0.36	3.01%	0.38	0.49%	0.45	3.10%	10.41	7.98%
Education	22.81	2.51%	0.11	0.50%	0.00	0.04%	0.92	1.18%	0.05	0.37%	5.18	3.97%
General knowledge	5.56	0.61%			0.13	1.05%	0.28	0.36%	0.10	0.67%	2.58	1.98%
sociology & psychology	30.81	3.39%	0.64	3.02%	0.12	0.98%	0.75	0.97%	0.04	326.00%	5.82	4.46%
Agri, forestry, fishery & livestock ind.	44.06	4.85%	1.93	9.03%	0.03	0.26%	6.34	8.16%	0.31	2.13%	5.18	3.97%
Transportation & Telecommunication	4.50	0.49%			0.09	0.73%	0.30	0.39%	0.08	0.51%	1.02	0.78%
Math & Computing	55.59	6.12%	1.29	6.05%	1.31	10.89%	5.46	7.03%	1.08	7.36%	10.13	7.76%
Medical science	160.86	17.71%	3.54	16.52%	0.24	2.02%	18.82	24.21%	0.66	4.46%	21.63	16.57%
Arts	3.05	0.34%			0.00	0.04%	0.48	0.61%	0.07	0.45%	0.51	0.39%
Tourism	0.73	0.08%							0.02	0.14%	0.53	0.41%
Total	908.27		21.33		12.05		77.73		14.69		130.53	

TABLE VI

ACCUMULATED AVERAGE GRANTS PER RESEARCHER BY PROJECTS TYPE ('91-'05)

20 research area	General research project		Specialty research project		National Defense research program		National S&T research program		Industry promotion & humancapital murturing program		Fresh researchers supported project	
	No.of applied researchers	Ave. grants (million)	No.of applied researchers	Ave. grants (million)	No.of applied researchers	Ave. grants (million)	No.of applied researchers	Ave. grants (million)	No.of applied researchers	Ave. grants (million)	No.of applied researchers	Ave. grants (million)
Engineering	5557	4.75	95	5.97	502	1.46	314	6.87	1467	0.72	2808	1.18
Medical science	3578	4.50	47	7.53	21	1.16	253	7.44	118	0.56	1672	1.32
Natural science	2254	8.91	66	10.40	73	2.72	235	8.24	106	0.67	945	2.45
Math & Computing	1900	2.93	23	5.61	101	1.30	159	3.44	187	0.58	1149	0.88
Management	1792	2.23	7	5.10	33	1.10	19	2.02	99	0.46	1345	0.77
Others	1380	2.39	6	4.25	21	1.44	24	3.29	10	0.50	214	0.94
Humanities	1095	1.74	9	3.85	2	1.86	26	2.93	3	0.81	524	0.65
sociology & psychology	1065	2.89	15	4.30	10	1.18	30	2.51	7	0.54	563	1.04
Education	1032	2.21	2	5.35	1	0.45	45	2.04	10	0.54	581	0.89
Agriculture, forestry, fishery & livestock ind.	915	4.82	25	7.70	3	1.05	113	5.61	53	0.59	332	1.56
General knowledge	401	1.39			5	2.53	15	1.87	16	0.61	323	0.80
Architecture & City planning	325	2.35	1	12.43	1	0.46	20	1.89	50	0.45	152	0.88
Sports	283	1.45			6	1.06	8	0.79	8	0.85	133	0.46
Law	205	1.89			1	0.61	17	2.43	4	0.72	122	0.66
Arts	193	1.58			1	0.47	20	2.39	13	0.51	82	0.62
Transportation & Telecommunication	187	2.40	3	6.78	9	0.98	7	4.35	18	0.46	118	0.86
Housecraft	185	2.69			1	1.56	8	2.25	26	0.47	157	1.08
Mass communication	173	1.70			1	2.83	16	3.06	7	0.58	114	0.74
Tourism	61	1.19							7	0.30	63	0.84
Craft technology	13	1.25							8	0.52	14	1.31

After glancing at the capital investment environment, we then turn to the structure of research talents. In general, numbers of researchers increased year by year at this period, from 3,700 in 1991 to 14,000 in 2005. It had a 4 times increment. However, referring to fig. 5, we find that the growth rate decreased. It would be an issue to see if research talents in Taiwan become saturated in these years. As we group scholars into three categories: (1.) senior researchers with age over 56, who started his/her academic career in 60s to 70s; (2.) mature researchers with age between 41 to 55, who starts academic career in 80s; and (3.) novices with age under 40, who starts the career in late 90s. It is found that the distributions of three age categories were 19%, 64%, and 17% among the scholars from fig. 6. Accompanying with the increment R&D investment by the government, researchers could gain more grants per commissioned projects. Taking mature researchers for example, they could be granted for 0.66 million per project per person. Mature researchers are the cores of Taiwanese research community nowadays.

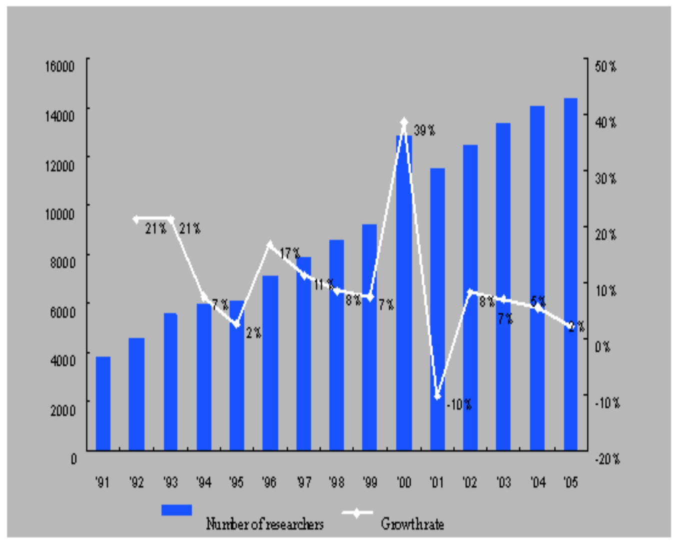

Fig. 5. Number of research talents and growth rate by year

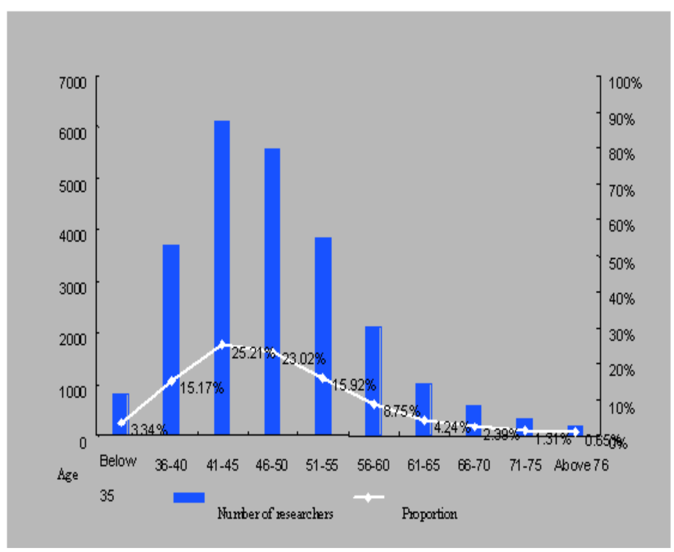

Fig. 6. Age distribution of total research talents ('91-'05)

However, when we take experience into account to analyze researcher's capacity, there is something interesting. Only 22% of research talents possess working experience in industries, whereas 64% of them have merely academic experience. The proportion remains the same as year goes by. How to bridge basic research and adopt it to utilize in industry should be a serious issue for the government (table VII). We also find that the position structure of researchers has an essential change. Due to some policy effects, the proportions of professor, associate professor, and assistant professor changed from 1991 to 2005. The rates changed from 1991 as 29%, 71%, and 0%, to 54%, 29%, and 17% in 2005.

We also notice from fig.7, commissioned projects do equip researchers with fundamental knowledge and skill to carry on next NSC granted projects. In mature researcher group, 85% of the researchers are able to receive NSC projects in 5 years after completing their previous NSC granted ones. Analysis also shows that only 14% of all the researchers received their NSC granted projects the first time. It means that most of the researchers are experienced and NSC nurtures research talents by commissioned projects. It has good effects and good cycle on researcher's career development. If we take total commissioned project years that one researcher possesses into

TABLE VII

PROPORTION OF DIFFERENT WORKING EXPERIENCE IN EACH AGE GROUP

Age group	Number of researchers with industrial experience	% (of total 20128)	Number of researchers with only academic experience	% (of total 20128)
26-30	3	0.01%	9	0.04%
31-35	83	0.41%	382	1.90%
36-40	591	2.94%	1978	9.83%
41-45	1169	5.81%	3239	16.09%
46-50	1061	5.27%	2992	14.86%
51-55	758	3.77%	2064	10.25%
56-60	430	2.14%	1094	5.44%
61-65	187	0.93%	551	2.74%
66-70	116	0.58%	297	1.48%
71-75	59	0.29%	175	0.87%
above 76	23	0.11%	86	0.43%
Total	4480	22.26%	12867	63.93%

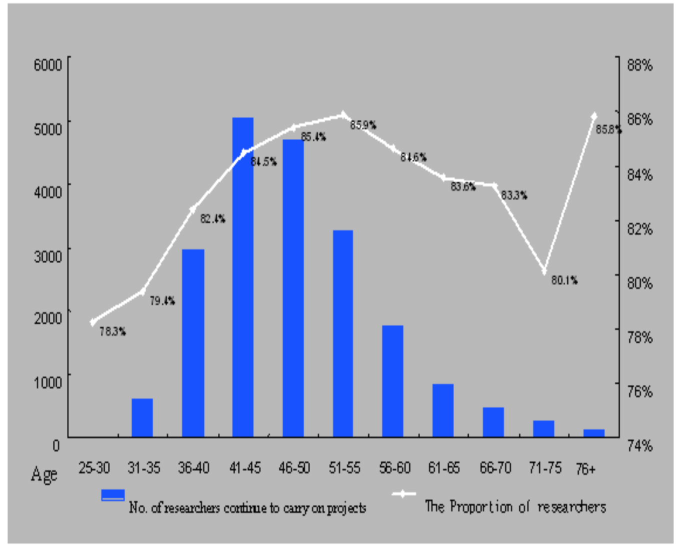

Fig. 7. Number and proportion of researchers to receive NSC projects again in 5 years after completing previous ones

account, we find that mature researchers have an average 6-10 project years. The average project number for each researcher also increases from 1991 to 2005. It starts with 1.3 projects per capita in 1991 to almost 9 projects per capita in 2005. Combining with the grants that received for researchers, we find that the more experience that a scholar possess, the more project numbers and grants would be received. Thus, in these 15 years investment, Taiwanese government cultivated quite a lot qualified talents and it reflected on the performance as well. Besides, we also take the "social participation" and "leadership" as our analysis elements. Leadership is the way to see if researchers have taken any position in his/her university, such as school dean. Social participation represents the extent that the researcher interacts with outside research society, such as a president of a council. From fig. 8, we can say that rather than neither leadership nor social participation for a researcher, the related project experience plays an important role in funding research projects.

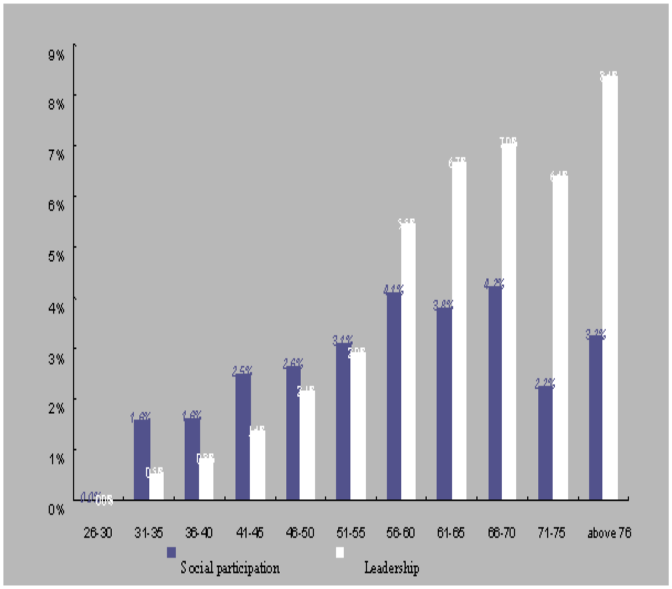

Fig. 8 Proportion of researchers in social participation and leadership by age groups

According to the indicators of three different age groups, it is no doubt that most scholars were mature and could perform research actively. It is also found that 83.7% of the researchers have Ph.D. degree, which contains 41% domestic ones and 59% international ones. Among the international diplomas, most of them (80%) are from the U.S. However, when we review the education backgrounds of researchers, it is found that structure of the highest education background changed. Senior and mature researchers possess more international diplomas and equip with international point of views than the fresh ones.

Now we turn to the career path of all scholars. It was observed that 60% of the scholars were once Principle Investigators (PI) or had participated in joint programs from table VIII. Besides, the proportion of scholars possessing experience in joint projects is increasing by years. More that 40% of the scholars complete the projects through collaborations. It was also noted that the average number of partners for scholars to work with is increasing, too. From fig. 9, there are 4% of scholars collaborate with other researchers from other academic fields. We also find that the degrees of collaboration are different among research fields.

TABLE VIII

DEGREE OF RESEARCH COLLABORATION ('91-05)

Total persons of project collaboration	Number of scholars
none	9484
1 person	5640
2-5 persons	6881
6-10 persons	1343
11-20 persons	386
20-50 persons	57
	23791

Total person-times of project collaboration	Number of scholars
0	9484
1 person-time	3438
2-5 person-times	6281
6-10 person-times	2422
11-20 person-times	1453
21-50 person-times	642
51-100 person-times	68
101+ person times	3
	23791

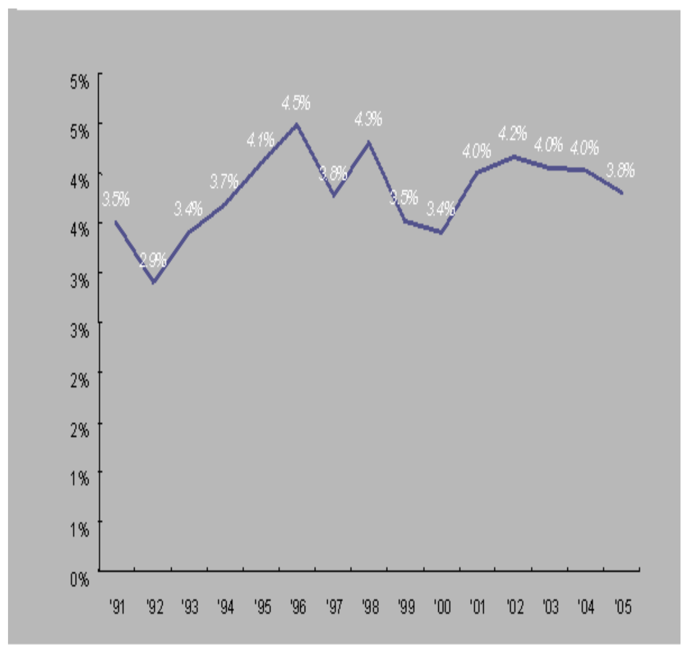

Fig. 9. Proportion of researchers to carry out cross-discipline projects by years

In "Engineering", "Medical science", and "Natural science", the collaboration degrees are higher than those in other areas. It reaches 65% whereas less than 35% in "Humanities" and "Law" (see Table IX).

TABLE IX

DEGREES OF COLLABORATION IN PROJECT BY 20 RESEARCH AREAS

20 research area	Total Number of researchers	Researchers with project collaboration	% of research collaboration
Engineering	5708	4067	71.25%
Medical science	3646	2565	70.35%
Natural science	2116	1403	66.30%
Math & Computing	1989	1215	61.09%
Management	2149	1123	52.26%
Education	1087	679	62.47%
Others	1373	609	44.36%
sociology & psychology	1188	576	48.48%
Agriculture, forestry, fishery & livestock ind.	907	471	51.93%
General knowledge	547	260	47.53%
Architecture & City planning	331	214	64.65%
Humanities	1286	345	26.83%
Sports	285	200	70.18%
Transportation & Telecommunication	188	111	59.04%
Arts	207	98	47.34%
Housecraft	226	137	60.62%
Mass communication	210	107	50.95%
Law	235	72	30.64%
Tourism	92	43	46.74%
Craft technology	21	12	57.14%

The last issue that this study would discus is the academic network of researchers through commissioned projects. Although there are connections among different research areas, we still find that researchers in engineering area are the cores for others to contact. They have integrated with scholars in "Natural science", "Math & computing", "Management", and "Medical science". Since the linkages are very dense, it reflects that the knowledge networks of Taiwanese researchers are very complicated and the researches are very diverse. Fig. 10 also shows that the research topics are quite varied and need knowledge from other areas to be digested and grasped. Moreover, in 128 sub-fields, we also notice that some fields show their widespread characteristics. "Computer science" has linkages and interactions among 92 sub-fields, whereas "Business administration" has 83. The collaboration network also suggests that medical engineering, molecule medicine, and technology management are emerging areas for research collaboration. (see Fig.11)

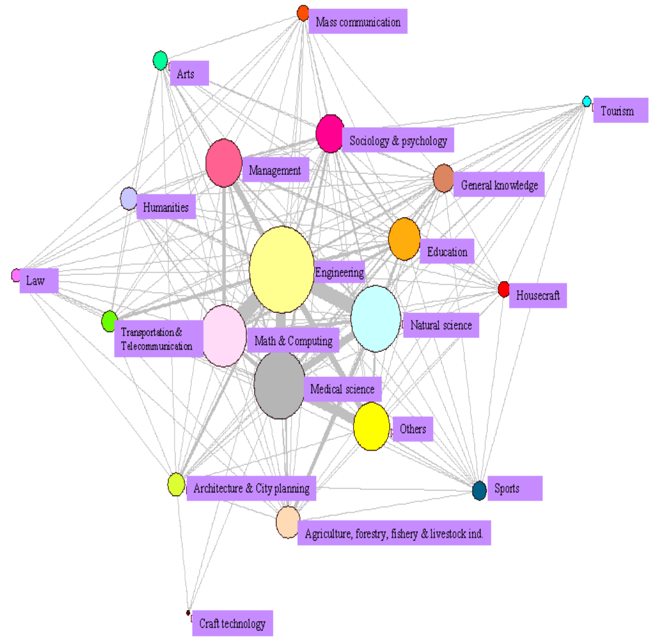

Fig. 10. Collaboration network of 20 main research areas

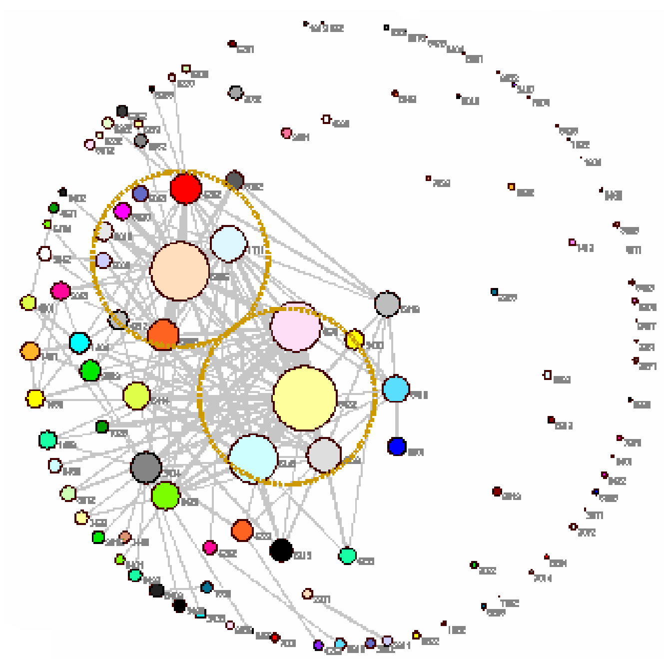

Fig. 11. Integration network of 128 sub-fields (only shows the sub-fields in which the collaboration researcher number is greater than 30)

Then we go through the 5 academic department of NSC. Fig.12 shows the collaboration network among 20 main research areas of the commissioned projects granted by Dept. of LS. There is a hub formed in this network, which is the “Medical science” area. It has strong linkages with “Natural science” and “Engineering”. However, the sizes of these three areas are not that different. Then we review the one from Dept. of EA. as fig. 13. “Engineering” does play an important role in this network organization. Its size is bigger than others’. In EA’s project collaboration network, it is dominated by two nodes, which are “Engineering” and “”math & computing”. The linkages among nodes are denser than those of other departments’. One reason is that numbers of researchers devoting in these disciplines are larger than in others. Reviewing the collaboration structure of Dept. of HS in fig.14, we find that size of each area is small respected to the previous two departments. There is not quite an obvious field to be hub. To conclude, Taiwanese researchers in Humanities usually do projects with people who are not in the same specific field. Besides, the projects in humanities and social science could be generalized so that many other academic fields would involve.

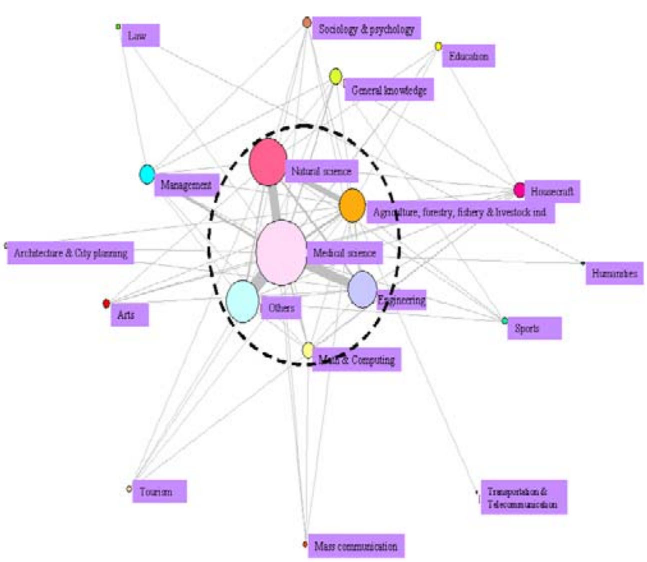

Fig. 12. Collaboration network of Dept. of LS’s commissioned projects

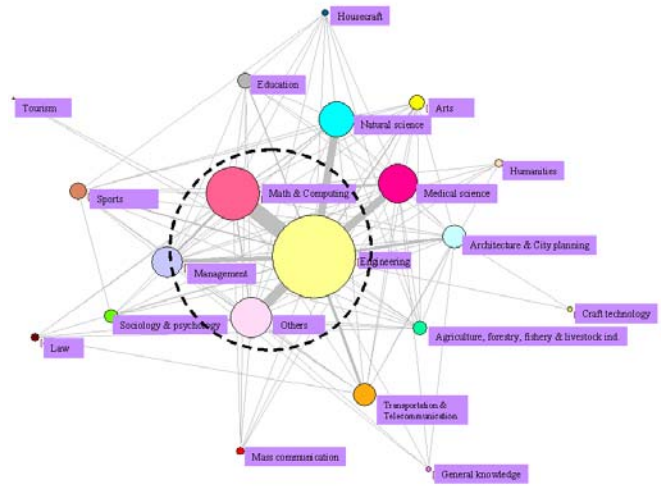

Fig. 13. Collaboration network of Dept. of EA’s commissioned projects

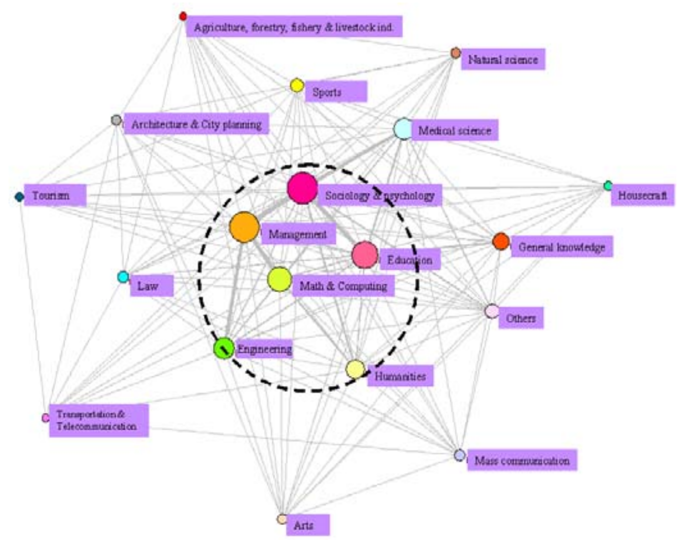

Fig. 14 Collaboration network of Dept. of HS’s commissioned projects

V. Conclusion

This study reveals that experiences in research projects would be beneficial to accumulate the relationships with other researchers. Not only extending the academic collaboration network but also strengthening the ability to carry on the projects does it assist in. By tracing the linkages and network, we are not able to grasp the interactions between scholars, but also help the scholars and authorities look for the main researchers of the relative and complementary knowledge in the field.

However, it still leave some issues for our later studies.

First, the production of researchers might not has a linear relationship with time span. Researchers in natural science field might have a peak in the middle of his career period, whereas scholars in humanities and social science might have a longer period to reach their career peaks. In the same way, funding investment and talents caltivating might have a non-linear relationship. Too much investment might not has positive impact on nurturing researchers.

Second, investment items rely on subjective judgement. What factors that affect academic productivity are still ambiguous and hard to reach consensus under different research environments. For example, funding might not have much impact on researcher's productivity in humanities and social science. However, it plays a crucial role in natural science. Numbers of graduate students could also be an important factor for a scholar to develop his/her career. Nevertheless, it still differs among research fields. Thus, the critical investment factors might still be influenced by academic politics.

What was criticized most in the past was that in order to take care of the whole academic communities, the authorities adopted truncate average method to allocate the research funds/resources. Moreover, it was not related much to the academic performance whether the research proposal was accepted. Nevertheless, NSC has a substantial change in the disposition of resources recently. Resources have a tendency to be centralized allocated in order to encourage outstanding research fellows. We would like to see in the coming future that Taiwan could train up several research talents through a sounder academic reputation mechanism and has an objectively well-developed environment for academic evaluation.

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