

# **The Institutional Arrangement and Performance Measure of National Priority Science and Technology Programs in Taiwan**

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## **Abstract**

Taiwan government has initiated several National Priority Science and Technology Programs (NPSTPs) since 1997, namely Hazards Mitigation, Telecommunications, Agricultural Biotechnology, Pharmaceuticals and Biotechnology, Genomic Medicine, Digital Archives, Systems on Chip, Nanotechnology, and e-Learning, through coordinating and integrating R&D resources nationwide. Distinguished from other government-funding R&D projects, they are formed by special institutional arrangements, across different government agencies at cabinet level, and their budgets have first priority to claim. This paper is aimed to analyze the performance of each NPSTP in terms of efficiency.

**Keyword:** S&T policy, R&D, KPI, efficiency

## ***1. Introduction***

In order to enhance national competitiveness, Taiwan government has initiated several National Priority Science and Technology Programs (NPSTPs) since 1997, namely Hazards Mitigation, Telecommunications, Agricultural Biotechnology, Pharmaceuticals and Biotechnology, Genomic Medicine, Digital Archives, Systems on Chip, Nanotechnology, and e-Learning, through coordinating and integrating research and development (R&D) resources nationwide. They are mission-oriented to meet the specific goals within a decade, including building up technological capacity, addressing major social and economic issues, and nurturing emerging industries. Distinguished from other government-funding R&D projects, they are formed by special institutional arrangements, across different government agencies at cabinet level, and their budgets have first priority to claim. In 2008 the funding of NPSTPs is NT\$11.24 billion, approximately US\$350 million, and it accounts for 14.6% of Executive Yuan Science and Technology budget.

Because of the particularity and importance of NPSTPs, in this paper, we will try to introduce the mechanism design and some important features of these programs. On the other hand, we will like to know the performance and efficiency of NPSTPs. Considering the characteristic of multi-outputs and the limitation of program number, Data envelopment analysis (DEA) is employed in this paper to proceed the efficiency comparison.

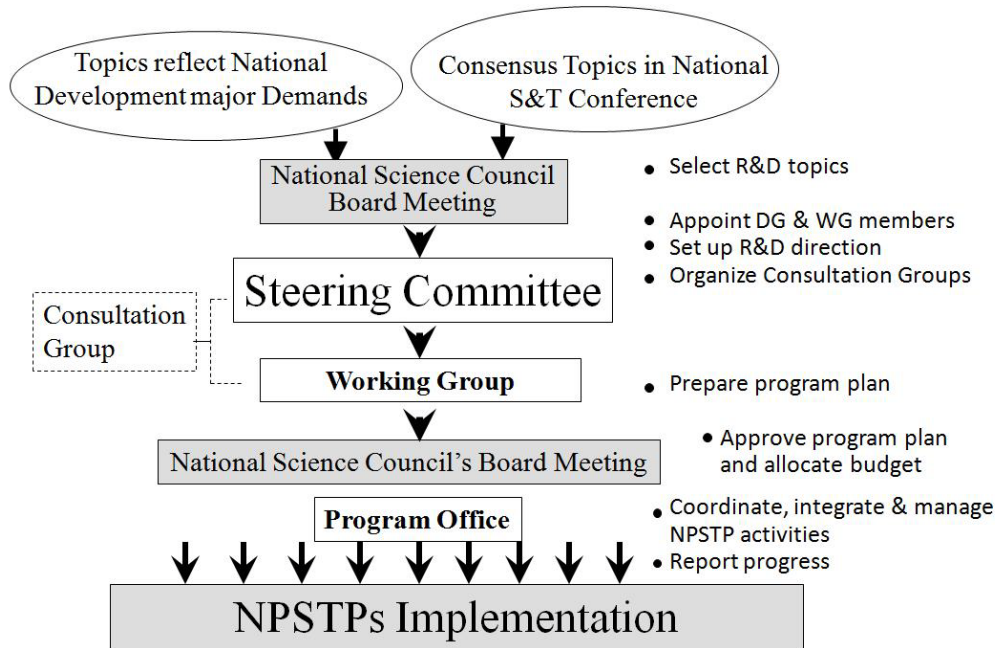
The remainder of this paper is organized as follows. Section 2 introduces some important features of NPSTPs, including development history and mechanism design. Section 3 presents the Empirical data and methodology of DEA and Malmquist productivity index. Section 4 reports the empirical results, including efficiency score of each NPSTP in different subset of output. The results of productivity change also reported in Section 4. Concluding remarks and policy implications are summarized in the final section.

## ***2. National Priority Science and Technology Programs (NPSTPs)***

NPSTPs should have clear and long term goals for developing innovative technology and significant contribution to industrial competitiveness and social welfare. Besides, NPSTPs should be those that need interdepartmental and interdisciplinary efforts and to be directed by the government with long term supports. Furthermore, NPSTPs should be those that engender great and vast impact, implemented through the cooperation and integration of R&D resources in academic, research, industrial and governmental instructions and formulated with international and perspective vision.

Each NPSTP has a Steering Committee and Working Group. Steering Committee is co-chaired by the Chairman of National Science Council (NSC) and a Minister without Portfolio, the Executive Yuan. The members of the committee are Vice Ministers and Deputy Directors responsible for R&D of related agencies of central government. The mission of the committee is appointing the Director-General, approving the members of Working Group, giving R&D direction, and organizing Consultation Group to assist its program plan preparation and implementation. As for Working Group, its mission is planning, coordinating, integrating, managing, and reporting progress to the steering committee and the NSC's Board Meeting. NPSTP's plans approved by NSC's Board meeting shall receive top priority in budget allocation, funded by NSC and related ministries or government agencies. NSC takes charge of schedule control, progress audit and performance evaluation.

## Flow Chart for Formation & Implementation of NPSTPs



Source: Planning & Evaluation Division, National Science Council, R.O.C.

## National Priority Science and Technology Programs

Program Name	Participating Agencies	Scope and Content
<b>Telecommunications (1998~2008)</b>	MOEA, MOTC, MOE, NSC	<ul style="list-style-type: none"> <li>✓ Broadband Internet</li> <li>• DWDM (dense wavelength division multiplexing)</li> <li>• Broadband Access</li> <li>• QoS Oriented Networking</li> <li>• Broadband Application</li> <li>✓ Wireless Communication</li> <li>• WB-CDMA WLL ( wide band code division multiple access systems for wireless local loop )</li> <li>• 3G Mobile Radio Systems</li> <li>• Wireless Internet and High Speed Wireless Local Area Network</li> <li>✓ National Broadband Experiment Network (NBEN)</li> </ul>
<b>Systems on Chip (2003~)</b>	MOEA, MOE, NSC	<ul style="list-style-type: none"> <li>✓ To establish the new design environment for SoC design</li> <li>✓ To establish the new service model for SoC design</li> <li>✓ To promote IP Mall service</li> <li>✓ To promote platform service</li> <li>✓ To promote innovative design</li> </ul>
<b>Nanotechnology (2003~)</b>	MOEA, NSC, MOE, Academia Sinica	<ul style="list-style-type: none"> <li>✓ Academic Excellence Research Program</li> <li>• Basic research on nanoscience</li> <li>• Synthesis, assembly and processing of Nanomaterials</li> <li>• Development of manipulation techniques and fabrication of functional nanodevices</li> <li>• Nano-biotechnology</li> <li>• Energy applications</li> <li>✓ Nanotechnology Industrialization Program</li> <li>• To enhance core facility and network</li> <li>• To speed up the development of nanotechnology</li> <li>• To develop and apply novel properties of nano-materials</li> <li>• To leverage the existing industrial knowledge and create new opportunities</li> <li>• To integrate new technical findings into the most competitive technologies and industries in Taiwan</li> <li>✓ Education Program</li> <li>✓ Core Facilities Program</li> </ul>
<b>Agricultural Biotechnology (1999~2008)</b>	COA, Academia Sinica, NSC, MOEA	<ul style="list-style-type: none"> <li>✓ Floral (Chrysanthemum and orchids)</li> <li>✓ Chinese herb based functional food.</li> <li>✓ Shrimp, Cobia, Grouper and Taiwan tilapia</li> <li>✓ Swine and chicken</li> <li>✓ Animal vaccine and adjuvant</li> <li>✓ Post-harvest technology for vegetables and fruits</li> <li>✓ Stress tolerant varieties, bio-fertilizers</li> </ul>

		<ul style="list-style-type: none"> <li>✓ Agricultural waste recycling</li> <li>✓ Functional genomics based technologies</li> <li>✓ Marker-assisted breeding.</li> <li>✓ Bioreactor technologies</li> <li>✓ Transgenic technology</li> <li>✓ Establishment of GMO assessment and accrediting systems</li> </ul>
<b>Pharmaceuticals and Biotechnology (2000~)</b>	DOH, NSC, MOEA	<ul style="list-style-type: none"> <li>✓ The research and the development of Chinese herbal medicines, new chemical drugs and protein drugs</li> <li>✓ Focus on four fields: cancer, diabetes, cardiovascular and neurological diseases</li> <li>✓ The preclinical evaluation unit, industry promotion unit, chemical core Lab</li> <li>✓ Academic- industry bridging program</li> </ul>
<b>Genomic Medicine (2002~)</b>	Academia Sinica, DOH, NSC, MOEA	<ul style="list-style-type: none"> <li>✓ Research Program <ul style="list-style-type: none"> <li>• Liver Cancer</li> <li>• Lung Cancer</li> <li>• Infectious Diseases</li> <li>• Highly Heritable Diseases</li> <li>• ELSI (Ethical, Legal, and Social Issues)</li> <li>• Innovative Research</li> </ul> </li> <li>✓ Industrial/Academic Collaboration Program</li> <li>✓ International Collaboration Program</li> <li>✓ National Core Facilities</li> </ul>
<b>Hazards Mitigation (1997~2006)</b>	MOEA, COA, MOI, NSC, DOH, EPA	<ul style="list-style-type: none"> <li>✓ Assessing hazard potentials of typhoon and earthquake (islandwide)</li> <li>✓ Reviewing and evaluating the present Hazards Mitigation Management System and Plans (islandwide)</li> <li>✓ Assessing risks of typhoon and earthquake (pilot project areas)</li> <li>✓ Simulating disaster scenario (pilot project areas)</li> <li>✓ Developing mitigation plans (model plan)</li> </ul>
<b>Digital Archives (2002~)</b>	Academia Sinica, NSC, MOE, CCA, NHL, NPM, NTU	<ul style="list-style-type: none"> <li>✓ Collections of indigenous cultures in Taiwan</li> <li>✓ Fishes, shell fishes, plants, insects, minerals and animals and birds in and around Taiwan</li> <li>✓ Archaeological, fossil and ancient calligraphy</li> <li>✓ Jade, porcelain and bronze</li> <li>✓ Image database of rare books</li> <li>✓ An archive of drawings in ancient books</li> <li>✓ Contemporary historical Archives</li> <li>✓ Selected gazetteer documents published</li> </ul>
<b>e-Learning (2003~)</b>	MOEA, MOE, COLA, CCA, DOH, NSC	<ul style="list-style-type: none"> <li>✓ Digital learning platform</li> <li>✓ Digital learning content and digital science park</li> <li>✓ E-Bag and digital learning-aided devices</li> <li>✓ Digital learning centers of the community</li> <li>✓ Reducing digital divide</li> <li>✓ Basic cognitive research for digital learning</li> <li>✓ Study of long-term digital learning policy, strategy and human resource development</li> </ul>

### ***3. Methodology and Empirical data***

#### ***3.1. Methodology of DEA***

Data envelopment analysis (DEA) is known as a mathematical procedure which Coelli (1996) use a linear programming technique to assess the efficiencies of decision-making units (DMUs). DEA also construct a non-parametric piecewise frontier of DMUs that owns optimal efficiency over datasets for the comparative efficiency measurement. Those DMUs which located at the efficiency frontier have their maximum outputs generated among all DMUs by taking the minimum level of inputs, are efficient DMUs, and own the best efficiency among all DMUs. The advantages of DEA do not need to specify either the production functional form or weights on different inputs and outputs and offer the detailed information on the efficiency of the unit to specific efficient units which can be identified as comparators (Hawdon, 2003; Lovell and Schmidt, 1993).

DEA models can be divided into the CCR model and the BCC model. The distinction between the two models lie in the assumption on returns to scale. The CCR model, which is the first DEA model suggested by Charnes et al. (1978), assumes constant returns to scale; whereas, the BCC model proposed by Banker et al. (1984) assumes variable returns to scale. DEA models are also distinguished by the objective of a model: maximize outputs or minimize inputs.

In the output-orientated CRS DEA model, we can assume there are data on K inputs and M outputs for each of N firms. For the  $i$ -th firm these are represented by the column vectors  $x_i$  and  $y_i$ . The  $K \times N$  input matrix X and the  $M \times N$  output matrix Y represent the data for all N firms. The output-oriented CRS DEA model then solves the following linear programming problem for  $i$  firm in each year:

$$\begin{aligned} & \max_{\theta} \theta, \\ & s.t. \quad -\theta y_i + Y\lambda \geq 0, \end{aligned} \tag{1}$$

$$x_i - X\lambda \geq 0,$$

$$\lambda \geq 0,$$

where  $\theta$  is a scalar and  $\lambda$  is a  $N \times 1$  vector of constants.

The value of  $\theta$  is used as the efficiency score for the  $i$ -th firms that satisfied  $0 \leq \theta \leq 1$ . The value of unity indicates a point on the frontier and hence a technically efficient firm, according to Farrell's (1957) definition.

### 3.2 Malmquist productivity index

Assuming that  $x_t \in R^{+M}$  and  $y_t \in R^{+L}$  denote the input and output vectors in the time  $t$ , and  $t = 1, 2, \dots, T$ , while the production technology is defined as capability transforming inputs into outputs. The technologically feasible input-output combinations can be categorized into an identical output oriented technology set (group)  $P^k(x)$ :

$$P_t^k(x) = \{y_t \text{ is obtainable from } x_t\} \quad (2)$$

The upper boundary of this output set refers to the frontier of group  $k$ .<sup>1</sup> Then, the output-oriented distance function in this group  $k$  is defined as in Shephard (1970):

$$D_t^k(x_t, y_t) = \inf_{\delta} \left\{ \delta > 0 : \left( \frac{y_t}{\delta} \right) \in P_t^k(x_t) \right\} \quad (3)$$

According to Fare *et al.* (1994), the Malmquist productivity index (MPI) for measuring the inter-temporal change in productivity on the basis of Caves *et al.* (1982) can be specified as:

$$MPI_{t,t+1}^k(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{D_{t+1}^k(x_{t+1}, y_{t+1})}{D_t^k(x_t, y_t)} \times \left[ \frac{D_t^k(x_{t+1}, y_{t+1})}{D_{t+1}^k(x_{t+1}, y_{t+1})} \times \frac{D_t^k(x_t, y_t)}{D_{t+1}^k(x_t, y_t)} \right]^{\frac{1}{2}} \quad (4)$$

In equation (4), the first term on the right-hand side of the equal sign is technical efficiency change (TEC). The second term is technical change (TC) expressed by a geometric mean of the shift in the frontier measured by using the points of

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<sup>1</sup> The output set is assumed to conform with the fundamental properties discussed in Fare and Primont (1995).

input-output combinations of periods  $t$  and  $t+1$  as reference.

The above approach can be extended by decomposing the (CRS) technical efficiency change into scale efficiency (SE) and “pure” (VRS) technical efficiency components (coelli, 1996). The CRS LP problem can be modified to account for VRS by adding the convexity constraint, and scale effect can be calculate as:

$$SE = TE_{CRS} / TE_{VRS} \quad (5)$$

### **3.3. Input and output data of NPSTPs**

In this paper, we collect a panel dataset of eight NPSTPs during the period 2004-2008. We have one input variable and five output variables from the seasonal report of National Science Council. The only input variable reported by NSC is the budget of each NPSTP, and it represents the expenditure of these national R&D programs. As for the output variables, the key performance indicators (KPIs) of NPSTPs are all included in this paper. In most of innovation production framework, investment in innovation activities are directed toward and intended for producing valuable knowledge (Wang and Huang, 2007), and these include patents count and academic publications. Yang *et al* (2009) chose royalty and licensing fees as one of the output variables to measure the economic output of innovation activities. As for the NPSTP, the goals of these programs are both comprehensive and diversified, and these characteristics can be observed from the KPIs of these programs. The KPIs of NPSTP include journal articles, patents count, technology transfer fees, investment promotion, and personnel training. Therefore, we classify journal articles and patents count as academic output, technology transfer fees and investment promotion as economic output, and personnel training as social output. The summary statistics of input and output data of NPSTP are showed in Table 1.

[Table 1 inserts here]

As showed in Table 1, average funding of NPSTPs of economic type (Telecommunications, Systems on Chip, and Nanotechnology) during 2004-2008 is

NT\$2.27 billion, higher than that of bio type (NT\$1.16 billion for Agricultural Biotechnology, Pharmaceuticals and Biotechnology, and Genomic Medicine) and social type (NT\$0.68 billion for Digital Archives, and e-Learning). As for the output variables, NPSTPs of economic type are also much higher the other two types, especially in terms of economic outputs. However, higher input and output values do not mean more efficiency. Therefore, before turning into the econometric analysis, it is useful for us to have a rough understanding about the input and output relationship between eight NPSTPs through a simple graphical analysis. Figure2-6 shows the output/input value of each output variable (or KPI) for the eight NPSTPs.

[Figure 1-5 inserts here]

As expected, NPSTPs of economic type perform better in terms of economic outputs, especially in investment promotion. As showed in Figure 4, one dollar input can induce about NT\$19 and NT\$11 of investment respectively in Telecommunications and Systems on Chip, and the output/input value of the other 6 programs are less than one dollar. In the respect of technology transfer fees, NPSTPs of economic type also have better performance than those of bio type and social type as showed in Figure 5.

As for the output variable of journal articles, e-Learning has the highest output/input value among eight NPSTPs, and Agricultural Biotechnology and NPSTPs of economic type have almost the same value as well. In the respect of personnel training, Agricultural Biotechnology has the highest output/input value, followed by the e-Learning and Systems on Chip program.

To sum up, NPSTPs of economic type outperform in the respect of investment promotion, technology transfer fees and patent count; while NPSTPs of bio type and social type perform better in the respect of journal articles and personnel training. Therefore, to measure the over-all efficiency of NPSTPs of different types, one shall take into account of all of output variables (KPIs) together at the same time.

## ***4. Empirical results***

### ***4.1. Efficiency analysis of DEA model***

As the objective of NPSTPs is supposed to maximize the outputs given budget constraints rather than to minimize the inputs, the output-oriented models are employed in this paper. As mentioned above, five output variables are reclassified into three subsets (academic, economic and social output), and efficiency scores are calculated in each case. We report the results of CCR and BBC model, but the discussion will mainly focus on CCR model. Table 2 shows the average efficiency score of eight NPSTPs in the three subsets of output during 2004-2008. As for the measure of academic output, Telecommunications, Nanotechnology and e-Learning outperform the other 5 programs, and their efficiency scores are all higher than 0.9. Genomic Medicine shows inefficiency in academic output, and has the lowest efficiency score of 0.39 particularly.

[Table 2 inserts here]

In terms of economic output, the average efficiency score of Telecommunication is 1, much higher than the other programs, so it implies that Telecommunication is robustly efficient unit. The efficiency scores of Genomic Medicine and Digital Archives are however less than 0.1. In fact, these results are not surprising and can respond to the phenomenon observed in Figures 3 and 4. The performance of Telecommunication is much better than the other programs in terms of economic output, and the gap is so huge that it causes the extreme result in efficiency scores.

As for the results of social output, Agricultural Biotechnology has the highest average efficiency score of 0.949, followed by e-Learning and System on Chip with 0.777 and 0.716 respectively. The efficiency scores of the other five programs are all lower than 0.5, which implies inefficiency.

In order to make a more comprehensive comparison, we calculate the efficiency score made up of the five outputs as showed in Table 3. Although we suffer from the

problem of deficient DMUs<sup>2</sup>, these results still can provide a rough measure of efficiency score. It shows that Telecommunication has the optimal efficiency during 2004-2008 particularly; System on Chip, Nanotechnology, Agricultural Biotechnology and e-Learning are all in the leading group with higher efficiency score as well; Pharmaceuticals and Biotechnology, Digital Archives and Genomic Medicine have inefficiency results in the combined measure of the five outputs however. In sum, although NPSTPs of economic type are not relatively impressive in terms of social output, they still outperform the other programs in a comprehensive comparison.

[Table 3 inserts here]

#### ***4.2. Malmquist productivity index***

Malmquist productivity index is used to measure productivity change and to decompose this productivity change into technical change and technical efficiency change. Technical change (TC) means the movement of frontier, and at the firm level, the shift out of frontier means technical progress. In this paper, the shift out of frontier can be viewed as the improvement in the institutional arrangement, mechanism design or operation of program. On the other hand, technical efficiency change is decomposed into scale efficiency change (SEC) and “pure” technical efficiency change (TEC). In this subsection, we will observe the change of efficiency and total factor productivity (TFP), and discuss the dynamic development of each NPSTP in terms of different output respectively.

Table 4 shows the results of TEC, TC, SEC and TFP in terms of academic output. The average technical efficiency change of these programs except Nanotechnology and Agricultural Biotechnology shows a downturn trend during 2004-2008. Particularly, the average change rate of Digital Archives is -29.7% annually, which implies that its technical efficiency becomes much worse during this period. The

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<sup>2</sup> Golany and Roll (1989) proposed that the number of DMUs must at least be twice of input and output variables. Deficient DMUs will result in overestimation of efficiency score.

average technical change rate is slightly increasing except Telecommunications. For System on Chip, Pharmaceuticals and Biotechnology, and e-Learning, the positive effect of technical change offsets the downturn of technical efficiency change, which results in a slight growth of TFP.

[Table 4 inserts here]

Turning to the result of economic output, one can see from Table 5 that NPSTPs of economic type have positive technical efficiency change and technical change growth rate, and thus have increasing TFP during 2004-2008. Agricultural Biotechnology has the same pattern as those of economic type. For Pharmaceuticals and Biotechnology, Genomic Medicine, Digital Archives, and e-Learning, all decline in technical efficiency change but increase in technical change at the same pace. Particularly, although its annual efficiency score shows inefficiency in section 4.1, Pharmaceuticals and Biotechnology still has positive TFP growth in terms of economic output because the decline in technical efficiency change is less than the increase in technical change growth.

[Table 5 inserts here]

As for the result of social output, System on Chip outperforms the other programs in the cross-period comparison. With 36.2% technical efficiency change growth and 55% TFP growth, System on Chip shows a significant improvement in personnel training. Pharmaceuticals and Biotechnology also improves both in technical efficiency change and in technical change. In short, all of NPSTPs except e-Learning show an increase in TFP, meaning that these programs have productivity growth in personnel training during 2004-2008.

[Table 6 inserts here]

Finally, we look at the results of five outputs combined altogether. As showed in Table 7, technical efficiency change rate is -5.8% and technical change rate is 10.3% on average for the eight NPSTPs. Consequently, most of these programs have improvement in TFP except Telecommunications and Digital Archives. To sum up,

TFP has a slight growth rate of 3.9% on average, meaning that the productivity of NPSTPs keeps growth during 2004-2008. In other words, NPSTPs have been running altogether in the right direction in the period of time

[Table 7 inserts here]

### ***5. Concluding remarks and policy implication***

As for the empirical results, NPSTPs of economic type significantly outperform the other two types in terms of academic and economic outputs. The reasons might be that most of the output variables, KPIs of NPSTPs, belong to short-term performance indexes, and these short-term indexes would favor those related to the well-established industries in most cases. These might explain the outstanding performances of Telecommunications, Systems on Chip, and Nanotechnology. Besides, Taiwan used to be well known for agricultural technology, so Agricultural Biotechnology has higher efficiency score in many aspects.

In contrast, Digital Archives, Pharmaceuticals and Biotechnology and Genomic Medicine have relatively lower efficiency score among eight NPSTPs. Their impacts and contributions could hardly be quantified, and thus would result in the lower efficiency score when measured by short-term performance indexes. The results come from efficiency analysis might provide some ideas in government resources allocation, however, in the decision-making process of science and technology policy, one shall consider more comprehensive factors to plan the long-term development for the sustainable growth of the economy.

## References

1. Caves, D. W., L. R. Christensen, and W. E. Diewert (1982), The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity, *Econometrica*, 50, 1393–1414.
2. Charnes, A., W.W. Cooper and E. Rhodes (1978), Measuring Efficiency of Decision Making Units, *European Journal of Operational Research*, 2, pp.429-444.
3. Coelli, T.J. (1996), *A Guide to Deap Version 2.1: A Data Envelopment Analysis (Computer) Program*. Department of Econometrics, University of New England, Armidale, Australia.
4. Fare, R., and D. Primont (1995), *Multi-output Production a Duality: Theory and Applications*, Boston: Kluwer Academic Publishers.
5. Fare, R., S. Grosskopf, M. Norris and Z. Zhang (1994), Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries. *American Economic Review*, 84, 66–83.
6. Farrell, M.J. (1957), The Measurement of Productive Efficiency, *Journal of the Royal Statistical Society, Series A, General*, 120, Part 3, 253-281.
7. Hawdon, D. (2003), Efficiency, Performance and Regulation of the International Gas Industry – a Bootstrap DEA Approach, *Energy Policy*, 31, pp.1167-1178.
8. Lovell, A.K. and S.S. Schmidt (1993), *Production Frontiers and Productive Efficiency, the Measurement of Productive Efficiency: Techniques and Applications*. Oxford University Press, New York.
9. Wang, E.C. and W.C. Huang (2007), Relative Efficiency of R&D Activities: A Cross-country Study Accounting for Environmental Factors in the DEA Approach, *Research Policy*, 36, pp.260-273.
10. Yang, C.H., J.L. Hu and C.P. Chen (2009), Innovation Environment and Different Output-oriented Innovation Efficiency Indexes, working paper.

Table 1 Summary Statistic of Input, Output variable of NPSTP, 2004-2008

Program type	Program name	Input fund (thousand dollar)	Academic output		Economic output (thousand dollar)		Social output
			journal articles	patents count	technology transfer fees	investment promotion	personnel training
Economic	Telecommunications	1,799,689	944	139	140,008	34,023,065	456
	System on Chip	1,995,693	971	77	78,622	22,205,040	1,991
	Nanotechnology	3,019,215	1,481	217	159,472	1,759,691	1,766
Biotechnology	Agricultural Biotechnology	682,568	355	9	20,856	49,342	825
	Pharmaceuticals and Biotechnology	1,218,479	428	34	15,341	315,224	193
	Genomic Medicine	1,582,176	447	9	2,025	8,601	421
Social	Digital Archives	709,935	240	5	1,693	15,873	82
	e-Learning	656,120	478	7	11,848	621,470	612
	Average	1,457,984	668	62	53,733	7,374,788	793

Table 2 Average Efficiency Score of NPSTPs—Academic, Economic and Social Output

Program type	Program name	Academic output		Economic output		Social output	
		CCR	BBC	CCR	BBC	CCR	BBC
Economic	Telecommunications	0.970	0.977	1.000	1.000	0.206	0.267
	System on Chip	0.785	0.836	0.630	0.656	0.716	0.825
	Nanotechnology	0.961	1.000	0.681	0.898	0.467	0.815
Biotechnology	Agricultural Biotechnology	0.717	0.845	0.416	0.818	0.949	0.999
	Pharmaceuticals and Biotechnology	0.543	0.662	0.166	0.225	0.138	0.171
	Genomic Medicine	0.390	0.446	0.018	0.020	0.218	0.276
Social	Digital Archives	0.523	0.604	0.049	0.215	0.084	0.271
	e-Learning	0.932	0.975	0.243	0.776	0.777	1.000
Average		0.728	0.793	0.400	0.576	0.444	0.578

Table 3 Average Efficiency Score of NPSTPs— All output

Program name	All output	
	CCR	BCC
Telecommunications	1.000	1.000
System on Chip	0.977	1.000
Nanotechnology	0.992	1.000
Agricultural Biotechnology	0.995	1.000
Pharmaceuticals and Biotechnology	0.543	0.664
Genomic Medicine	0.390	0.470
Digital Archives	0.526	0.604
e-Learning	0.981	1.000
Average	0.800	0.842

Table 4 Malmquist productivity index—Academic output

Program name	Academic output			
	TEC	TC	SEC	TFP
Telecommunications	0.966	0.993	0.997	0.959
System on Chip	0.987	1.059	1.009	1.046
Nanotechnology	1.047	1.012	1.047	1.059
Agricultural Biotechnology	1.000	1.062	1.000	1.062
Pharmaceuticals and Biotechnology	0.948	1.071	0.997	1.016
Genomic Medicine	0.922	1.080	1.013	0.996
Digital Archives	0.703	1.111	0.944	0.780
e-Learning	0.998	1.092	0.979	1.090
Average	0.941	1.059	0.998	0.996

Table 5 Malmquist productivity index—Economic output

Program name	Economic output			
	TEC	TC	SEC	TFP
Telecommunications	1.000	1.136	1.000	1.136
System on Chip	1.388	1.289	1.002	1.790
Nanotechnology	1.105	1.191	0.987	1.316
Agricultural Biotechnology	1.021	1.191	0.878	1.215
Pharmaceuticals and Biotechnology	0.851	1.191	0.841	1.013
Genomic Medicine	0.673	1.191	0.996	0.802
Digital Archives	0.340	1.191	1.219	0.405
e-Learning	0.837	1.191	0.714	0.996
Average	0.843	1.195	0.945	1.008

Table 6 Malmquist productivity index—Social output

Program name	Social output			
	TEC	TC	SEC	TFP
Telecommunications	0.918	1.138	1.146	1.045
System on Chip	1.362	1.138	1.144	1.550
Nanotechnology	0.989	1.138	1.091	1.125
Agricultural Biotechnology	0.988	1.138	0.988	1.124
Pharmaceuticals and Biotechnology	1.043	1.138	1.084	1.187
Genomic Medicine	0.889	1.138	1.116	1.012
Digital Archives	0.991	1.138	1.874	1.128
e-Learning	0.744	1.138	0.744	0.847
Average	0.978	1.138	1.115	1.113

Table 7 Malmquist productivity index—All output

Program name	All output			
	TEC	TC	SEC	TFP
Telecommunications	1.000	0.995	1.000	0.995
System on Chip	1.031	1.302	1.031	1.342
Nanotechnology	1.011	1.083	1.011	1.094
Agricultural Biotechnology	1.000	1.123	1.000	1.123
Pharmaceuticals and Biotechnology	0.948	1.071	0.992	1.016
Genomic Medicine	0.922	1.094	1.045	1.009
Digital Archives	0.701	1.112	0.941	0.779
e-Learning	0.975	1.064	0.975	1.037
Average	0.942	1.103	0.999	1.039

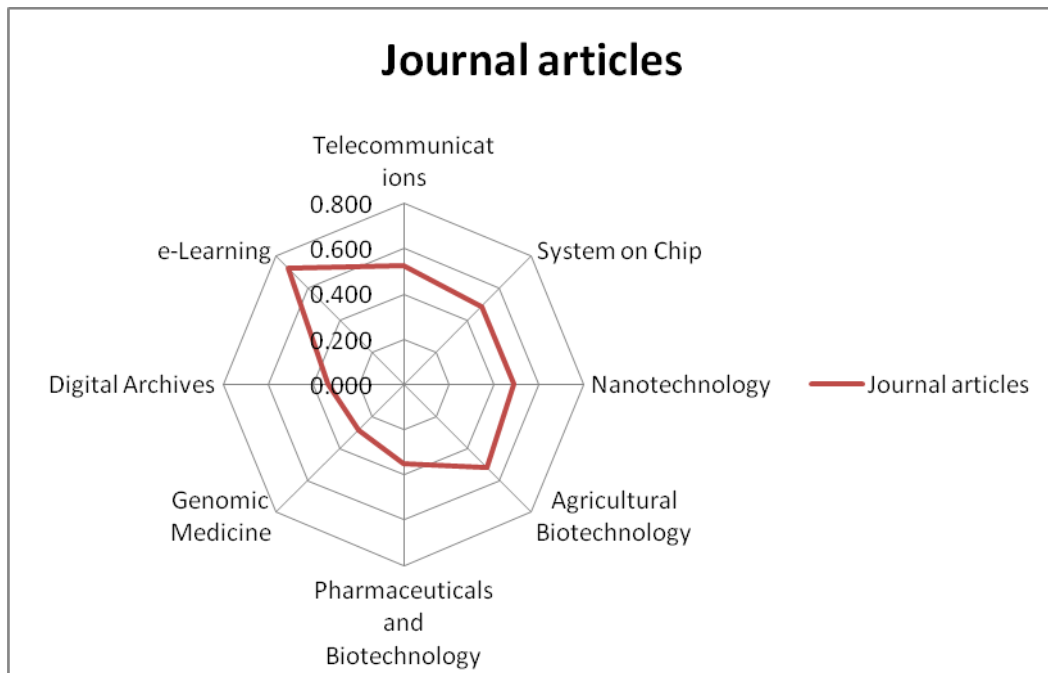


Figure 1 Output/input ratio of Journal articles per NT\$ million

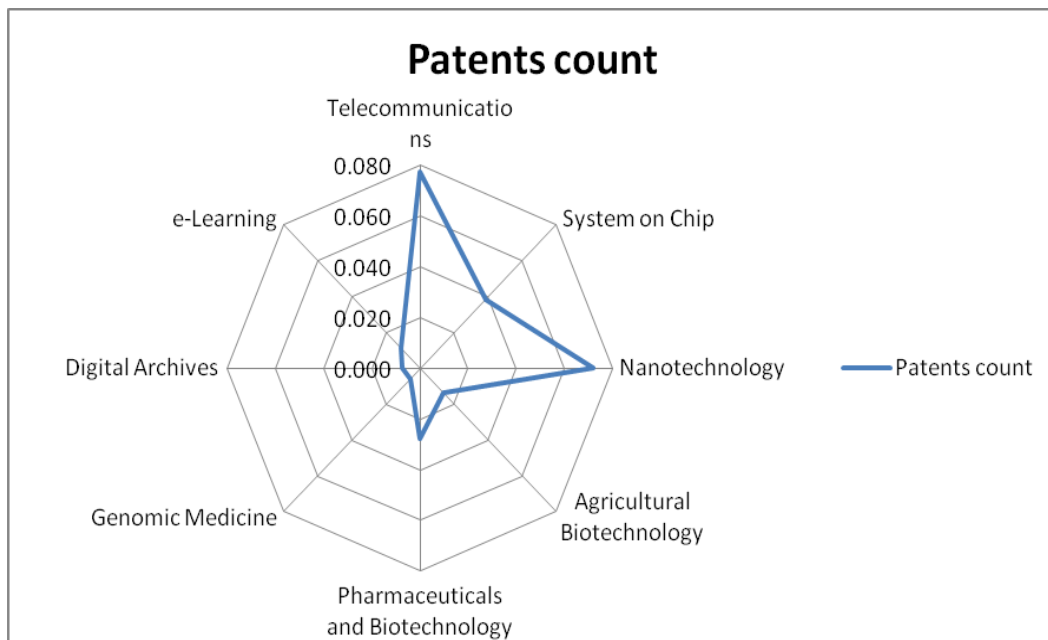


Figure 2 Output/input ratio of Patent count per NT\$ million

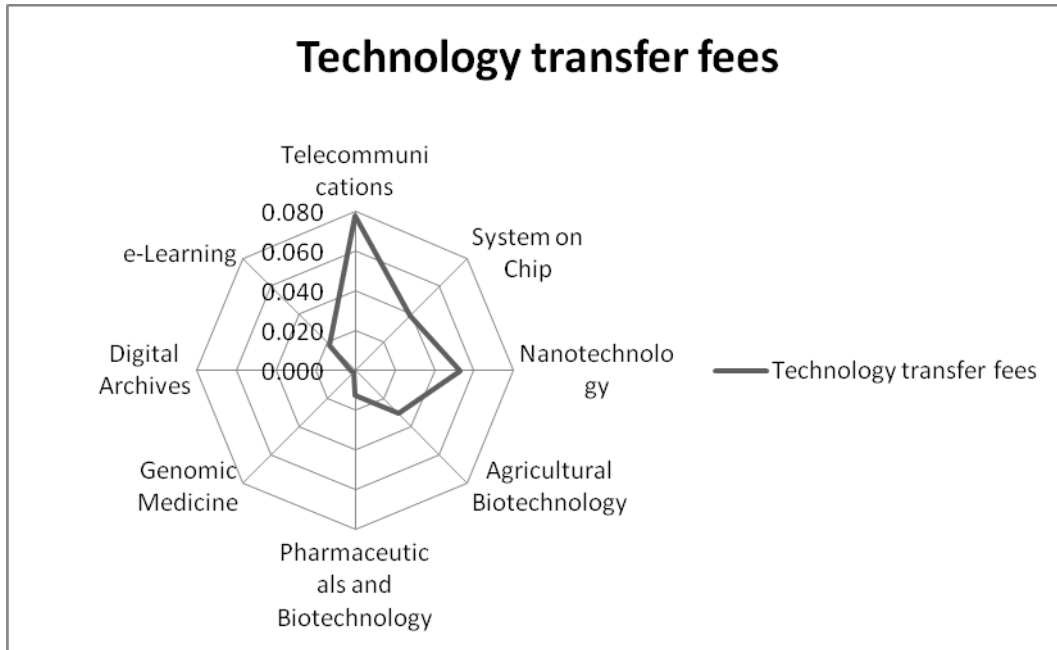


Figure 3 Output/input ratio of Technology transfer fees per NT dollar

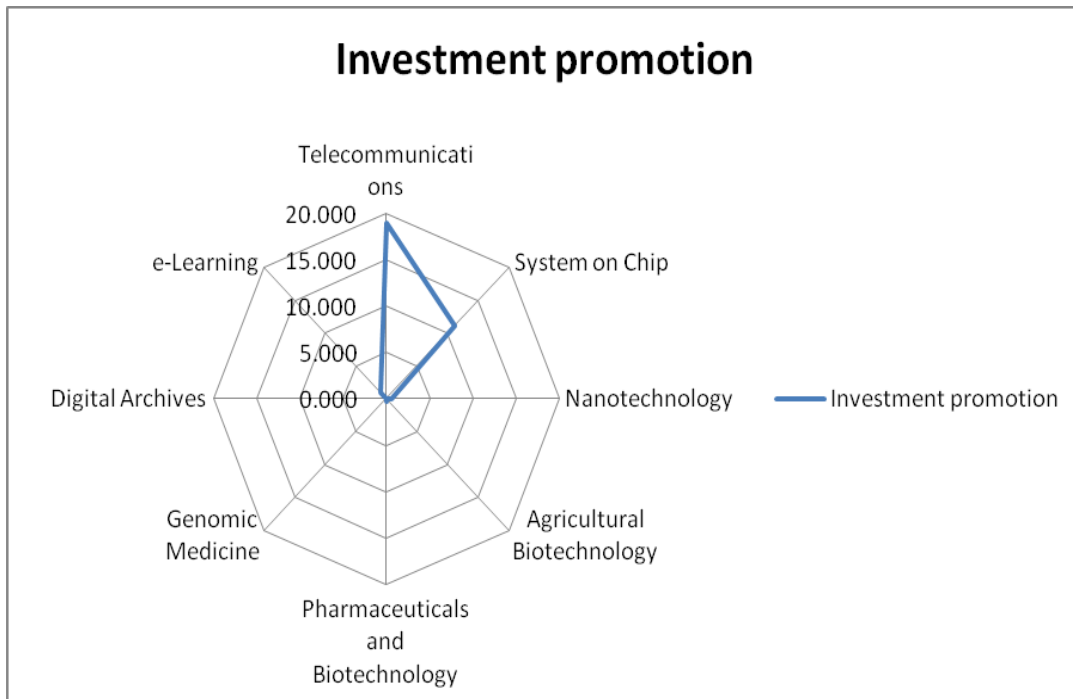


Figure 4 Output/input ratio of Investment promotion per NT dollar

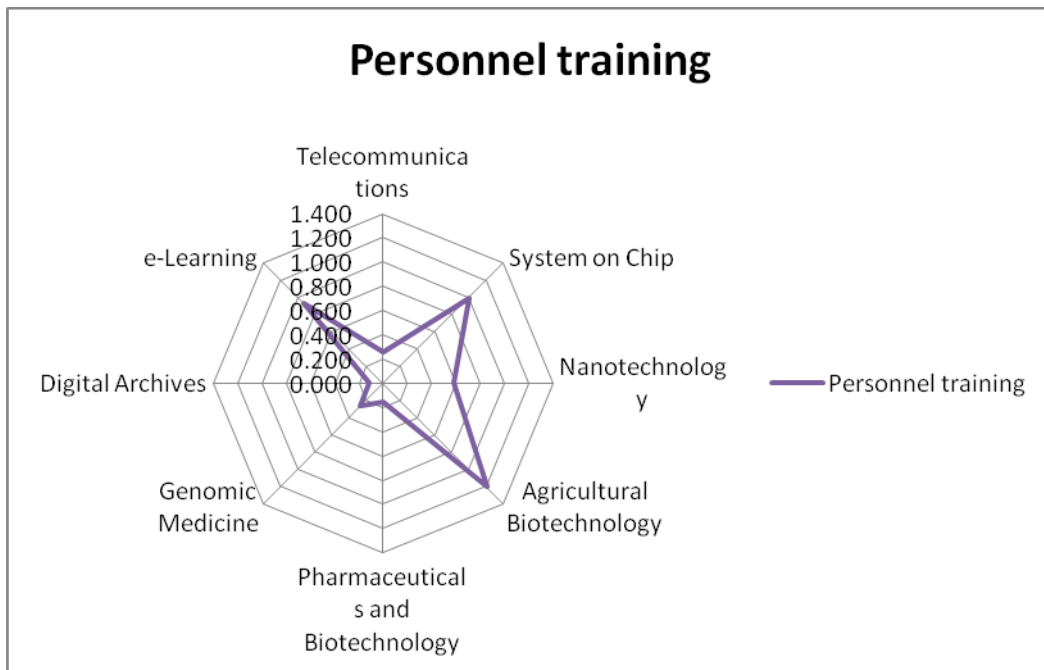


Figure 5 Output/input ratio of Personnel training per NT\$ million