A Structural Analysis of World Competitiveness by the IMD --The Science and Technology Case

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Abstract *Many people in Japan are interested in and quote frequently from the World Competitiveness Yearbook (WCY) published by the IMD[1] (International Institute for Management Development 1986-). They are pleased and disappointed in turn by the Japanese ranking, but they have never analyzed it in detail and it does not seem to be well understood. In order to rectify this situation, we analyzed the statistics on science and technology (S&T) from the 1990-2002 WCY. The results are as follows:*

- *The S&T statistics (about 26 criteria) can be classified into four groups; (i) hard and absolute criteria, such as Research and Development (R&D) expenditure and R&D personnel; (ii) hard and relative criteria, such as R&D expenditure per GDP and R&D personnel per capita; (iii) soft and national technology management; and (iv) soft and S&T human resources.*
- *The trend of each criteria group seems to reflect the real trend of each country. This indicates the usefulness of criteria grouping.*
- *A covariance structure analysis applied to the statistics indicates clearly an existence of a structure among economic development, national technology management, and R&D efforts. The results of these analyses demonstrate how to understand and use the IMD's World Competitiveness Yearbook.*

1 Introduction

The "world competitiveness" ranking compiled by the IMD is widely quoted by various bodies, particularly in Japan. However, its contents are not deeply analyzed, are superficially used, and are often quoted in a misleading way. In many cases, there have been no detailed analyses at all. Furthermore, the science and technology

[1] " IMD is one of the world's leading business schools with over 50 years' experience in developing the leadership capabilities of international business executives at every stage of their careers." http://www02.imd.ch/

(S&T) competitiveness ranking has not been issued since 2001. Concerns regarding its absence are strong, and there is great demand for an updated report in Japan.

The purpose of this research is to analyze the S&T World Competitiveness (STWC) rankings using the criteria[2] from the IMD reports, and to supply the results to those interpreting the rankings so they can understand and use the statistics appropriately. To be concrete, the goals are:

- To apply multivariate analysis to the IMD's S&T criteria in order to clarify the structure of criteria used. The IMD adds the values of many criteria to arrive at a statistic for world competitiveness. Although we approve of this method and appreciate the usefulness of its results, we insist on the necessity of a structural analysis of the criteria used. We also think that a trend analysis of the criteria clusters that compose the structure is necessary.
- To examine the content and meaning of each criteria cluster and what it indicates. We have established four criteria clusters: (a) S&T Power; (b) S&T Activity Density; (c) National Technology Management; and (d) S&T Human Resources.
- To identify appropriate criteria based on the analyses mentioned above, and to develop their indicators. We analyze the STWC trends of chosen countries.
- To develop an indicator for each criteria cluster. We then compare the trends of chosen countries.
- To clarify the relationships among clusters by application of covariance structural analysis to the criteria.
- To clarify problems with the STWC criteria and method used in order to develop a more appropriate use of the competitiveness rankings.

2 Data Used

The IMD has published its World Competitiveness Yearbook since 1986. However, its variables have become more substantial since 1988. Because the IMD calls these variables criteria, we also use this term. S&T was one of eight fields reported in the 2000 Yearbook. However, all criteria have been integrated into four fields ("Input Factors" in the WCY) since the 2001 Yearbook, and the IMD has never calculated since then. The majority of criteria comprising S&T World Competitiveness belong now to "Scientific Infrastructure," one of the sub-factors comprising the "Infrastructure" input factors, while others belong to "Technological Infrastructure." In addition, the publication year of the Yearbook differs from the measurement years of the criteria, and the measurement years vary in the same Yearbook among criteria because the IMD tries to adopt the most recent data. Moreover, some questions changed slightly in the period from 1988 to 2002, although their titles are the same.

[2] The variables or statistics used in the IMD reports are called "criteria."

The IMD used 26 criteria for STWC in the 2000 Yearbook. Table 1 shows the use or existence of these criteria by their measurement years. The symbol (o) indicates the existence of the criterion, while the symbol (-) indicates non-existence.

Table 1. S&T Criteria Used

No.	Criteria (abbreviation)	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02
1	Total Expenditure on R&D (RdExp)	-	o	o	o	o	o	o	o	o	o	o	o	o	-	-
2	Total Expenditure on R&D per capita (RdePc)	-	o	o	o	o	o	o	o	o	o	o	o	o	-	-
3	Total Expenditure on R&D % (RdePg)	-	o	o	o	o	o	o	o	o	o	o	o	o	-	-
4	Business Expenditure on R&D (BusRde)	-	o	o	o	o	o	o	o	o	o	o	o	o	-	-
5	Business Expenditure on R&D per capita (BusRdePc)	-	o	o	o	o	o	o	o	o	o	o	o	o	-	-
6	Total R&D Personnel Nationwide (RdPrs)	-	o	-	o	o	o	o	o	o	o	o	o	o	-	-
7	Total R&D Personnel Nationwide per capita (RdpPc)	-	o	-	o	o	o	o	o	o	o	o	o	o	-	-
8	Total R&D Personnel in Business Enterprise (BusRdp)	-	o	-	o	o	o	o	o	o	o	o	o	o	-	-
9	Total R&D Personnel in Business Enterprise per capita (BusRdpPc)	-	o	-	o	o	o	o	o	o	o	o	o	o	-	-
10	Qualified Engineers (QualEng)	-	-	-	o	o	o	o	o	o	o	o	o	o	o	o
11A	Information Technology Skills (InfoTek)	-	-	-	-	-	-	-	-	-	-	-	o	o	o	o
11B	Computer Literacy	-	-	-	-	o	o	o	o	-	-	-	-	-	-	-
12	Technological Cooperation (TekCoop)	-	-	-	-	o	o	o	o	o	o	o	o	o	o	o
13A	Knowledge Transfer (CuCoop)	-	-	-	-	-	-	-	-	-	-	-	o	o	o	o
13B	Research Cooperation	-	-	-	-	o	o	o	o	o	o	o	-	-	-	-
14	Development and Application of Technology (TekDevApl)	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
15A	Relocation of R&D Facilities (RdFcl)	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
15B	Relocation of Production	-	-	-	-	-	-	o	o	-	-	-	-	-	-	-
16	Nobel Prizes (Nbl)	o	o	o	-	-	o	o	o	o	o	o	o	o	o	-
17	Nobel Prizes per capita (NblPc)	o	o	o	-	-	o	o	o	o	o	o	o	o	o	-
18	Basic Research (BasRes)	-	-	-	o	o	o	o	o	o	o	o	o	o	o	o
19	Science and Education (SciEdu)	-	-	-	-	-	-	-	o	o	o	o	o	o	o	o
20A	Interest in Science and Technology (StYouth)	-	-	-	-	-	-	-	-	-	o	o	o	o	o	o
20B	Engineering Science	-	-	-	-	o	o	o	o	-	-	-	-	-	-	-
21	Patents Granted to Residents (PtnRes)	-	o	o	o	o	o	o	o	o	o	o	o	-	-	-
22	Changes in Patents Granted to Residents (ChngPtn)	-	o	o	o	o	o	o	o	o	o	o	o	-	-	-
23	Securing Patents Abroad (PtnAbrd)	-	o	o	o	o	o	o	o	o	o	o	o	-	-	-
24A	Patent and Copyright Protection (PtnProt)	-	-	-	-	-	-	-	-	-	-	-	o	o	o	o
24B	Intellectual Property	-	-	-	o	o	o	o	o	o	o	o	-	-	-	-
25	Number of Patents in Force (PtnFrc)	-	o	o	o	o	o	o	o	o	o	o	o	-	-	-
26	Financial Resources (FinaRes)	-	-	-	-	o	o	o	o	o	o	o	o	o	o	o

In the table, the soft criteria are underlined. Where the contents of questions having the same title differed, we attach the branch sign A or B to the same criteria number. In the case of the Nobel Prize, the mean values of the past several years were used in recently published Yearbooks. The abbreviations of the criteria are shown in parentheses.

The 26 criteria can be divided into two groups as follows:

1. Hard criteria: statistics such as research and development (R&D) expenditure and R&D personnel. These total 15 criteria (see table 1). They can be further divided into two sub-groups, absolute and relative. The hard absolute criteria are statistics such as R&D expenditure and R&D personnel, while the hard relative criteria are obtained by dividing the hard absolute criteria by the population or GDP. Examples are R&D expenditure per GDP and R&D personnel per capita.
2. Soft criteria: the IMD survey questions. The measurement values are the means of the responses to the questions. There are 11 criteria, all of which are underlined in table 1. The responses are standardized as follows: the best by ten, the worst by zero, and the moderate by five.

3 Structure of the Criteria: Results of the Multivariate Analysis

We analyzed relationships among the criteria comprising the STWC to clarify the structure of the criteria. In order to apply factor analysis,

- We used the criteria in the 2001 Yearbook. Initially, we expected to use all 26 criteria. However, we decided not to use "Number of Patents in Force (PntFrc)," firstly, because some advanced countries such as Italy, New Zealand, and Britain lacked its values, and secondly and more importantly, because it had only very low correlations with other criteria.
- We analyzed all countries that had measured values for all 25 criteria. As a result, 33 countries were analyzed. However, the United States lacked values for the criteria concerning the number of R&D personnel. The world average seemed to be substituted for the missing value according to the IMD Yearbook. That is, the standardized value of the missing criterion was presumed to be 0. We thought that such presumption was improper. Therefore, in the case of the number of R&D personnel (RdPrs) of the United States, we estimated its 1999 value by a simple linear regression analysis using past statistics in 1991, 1993, 1999. We used the following estimation formula:

  $$RdPrs = -12{,}581{,}400 + 6{,}800Y,\ R = 0.930,\ R2 = 0.865,$$

  where, RdPrs = "Total R&D Personnel Nationwide," and Y=Year.
  As a result, we obtained 1,011,800. After this value was divided by the population, "Total R&D Personnel Nationwide per capita (RdpPc)" in 1999 = 3.704 was obtained.

  The values of "Total R&D Personnel in Business Enterprise (BusRdp)" have never existed in the United States. The criterion RdPrs analyzed above was the criterion having the highest correlation coefficient. Therefore, we estimated the value of BusRdp in 1999 using the following formula:

BusRdp = 36.222 + 0.59521 x RdPrs, R= 0.971, and R2 = 0.942.
To obtain this formula, we used the data of the developed countries, that is, France, Germany, Japan, and the U.K., because there were great similarities among them.

"Total R&D Personnel Nationwide per capita (RdpPc)" had the closest correlation with "Total R&D Personnel in Business Enterprise per capita (BusRdpPc)." The expectation formula was BusRdpPc = -0.2460 + 0.59496 x RdpPc with R = 0.926, and R2 = 0.858. For the development of this formula, we used the data of all countries except the United States, that is, 32 countries. The reason was that the standard deviation seemed small and steady.

After completing these calculations, we obtained a data matrix of 25 criteria and 33 countries, which had no missing values. In order to understand the quantitative relationships among criteria, we applied factor analysis to the data matrix. The factor loadings obtained by the principal axis method were rotated by Varimax rotation. The figure below shows the factor loadings of the first and the second factors. The accumulated ratios of the Eigen values were 54.0% in the first factor, and 76.9% in the second factor.

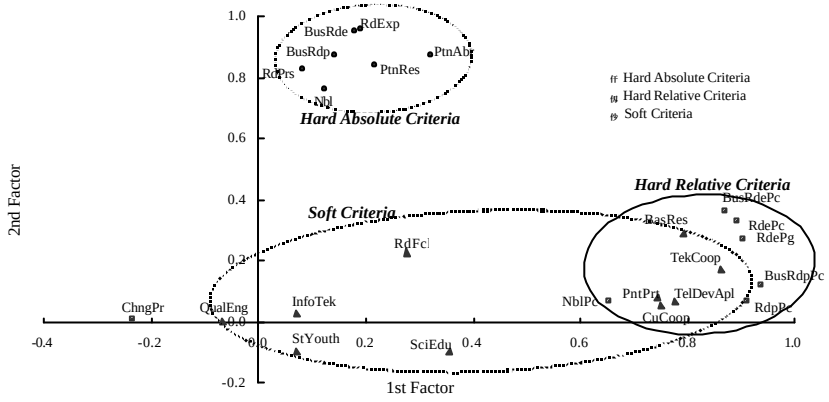

Figure 1. Factor Loadings of the S&T Criteria

This figure clearly shows the following points:

- All hard absolute criteria (?) are located close to each other in the upper part of the figure and separated from the other criteria. They compose one cluster.
- Similarly, all hard relative criteria ( ) except one criterion are also located close to each other in the right part of the figure. They compose another cluster, which is statistically independent from the first cluster.
- The criterion "Changes in Patents Granted to Residents (ChngPtn)" is an exception to the second cluster, because it is located at the left end, that is, the

opposite side of the cluster. ChngPtn is a kind of growth rate, and therefore different from the other hard relative criteria that are not of the growth rate type but of the density type. We thought that this was the reason why ChngPtn was located apart from the other relative criteria, and that in this case the quantitative analysis was very useful and practical. In our analysis, this criterion is thereafter not to be adopted.

- It is possible and might be useful to calculate the growth rates of some hard criteria to add them to the S&T criteria. They might improve the possibility that the S&T criteria come to reflect the situation of the STWC of each country more accurately. We believe that this will be an attractive subject in the future.
- The soft criteria (?) are located along the X-axis, and show a different behaviour from the hard criteria. This indicates that the soft criteria have a different quantitative characteristic, and that it is therefore appropriate to analyze the groups of criteria separately. However, we should also recognize that a number of soft criteria are closely related to hard relative criteria.

3.1 Structure of the Hard Criteria

We applied factor analysis to the hard criteria comprising the STWC, excluding the criterion "Changes in Patents Granted to Residents (ChngPtn)" after our consideration of criteria characteristics as discussed above. The factor loadings obtained by the principle axis method were rotated by Varimax rotation. The accumulation ratios of the Eigen values were 57.1% in the first factor and 80.2% in the second factor. The analysis was applied not only to the 2001 Yearbook, but also to the criteria of the measurement years from 1989 to 2000. We omitted the latter findings because we obtained very similar results to those of the 2001 Yearbook.

They indicate that the hard absolute criteria and the hard relative criteria are clearly separated, as expected from the previous analysis. Based on the characteristics of the criteria, we called the cluster of the hard absolute criteria "S&T Power," and the cluster of the hard relative criteria "S&T Activity Density."

3.2 Structure of the Soft Criteria

The factor analysis was applied to the soft criteria (see table 2), and the principal axis method and the Varimax rotation were executed similarly. The accumulated ratios of the first and second factors were 50.4% and 70.4% respectively. All the soft criteria in the 2001 Yearbook were measured in 2001.

After the analysis, we obtained figure 2. It shows that, with one exception, the soft criteria can be divided to the following two clusters:

1. The criteria belonging to the first cluster are located in the lower right of the figure; in other words, they have large factor loadings of the first factor. "Development and Application of Technology" (no. 14 in table 2), "Financial Resources" (26), "Company-University Cooperation" (13), "Technological Cooperation" (12), "Basic Research" (18), and "Patent and Copyright Protection" (12) belong to this cluster. We thought that a common

characteristic among these criteria is technology management at the national level. Therefore, we named the cluster "National Technology Management."

2. Those belonging to the second cluster are located in the upper left of the figure. "Science and Education" (10), "Qualified Engineers" (11), "S&T and Youth" (19), and "Availability of Information Technology Skills" (20) belong to the cluster. We thought that a common characteristic of this cluster is the fostering of S&T human resources. Therefore, we named it "S&T Human Resources."

Table 2. S&T Soft Criteria

No.	Criteria
10	Qualified Engineers, "Qualified engineers are not or are available in your country's labor markets" (QualEng)
11	Availability of Information Technology Skills, "Qualified information technology employees are not or are available in your country's labor market" (InfoTek)
12	Technological Cooperation "Technological cooperation is lacking or is common between companies" (TekCoop)
13	Company - University Cooperation "Technology transfer between company and universities is insufficient or is sufficient" (CuCoop)
14	Development and Application of Technology "Development and application of technology is constrained or is supported by the legal environment" (TekDevApl)
15	Relocation of R&D Facilities "Relocation of R&D facilities is or is not a threat to the future of your economy" (RdFcl)
18	Basic Research, "Basic research does not or does enhance long-term economic and technological development" (BasRes)
19	Science and Education "Science is not or is adequately taught in compulsory schools" (SciEdu)
20	Science and Technology and Youth "Science & technology does not interest or interests the youth of your country" (StYouth)
24	Patent and Copyright Protection "Patent and copyright protection is not or is enforced in your country" (PntPrt)
26	Financial Resources "Lack of sufficient financial resources constrains or does not constrain technological development" (FinaRes)

The criterion "Relocation of R&D Facilities" is located at the intersection of the two clusters. On the one hand, it has the characteristic of technology management at national level because it is one of the most important national S&T strategies. On the other hand, the criterion has the characteristic of fostering S&T personnel.

The Relocation of R&D Facilities concerns itself with such important issues as how to foster new talent for relocated facilities, how to hire excellent researchers from overseas, how to establish cooperation teams, and so on. In short, this criterion has two characteristics at once. If this is admitted, it seems appropriate to assume the contribution degree to each cluster to be half (0.5) respectively.

Similarly, we applied factor analysis to the criteria measured in the same year from 1992 to 2002 respectively (see table 1). We obtained results similar to the analysis of criteria in the 2001 Yearbook as noted above in the case of "National Technology Management," while the number of criteria that compose "S&T Human Resources" has increased over the years. Therefore, it cannot be said that they have quite the same structures. The reason is that the number of criteria has increased over time and the meanings of these criteria have changed.

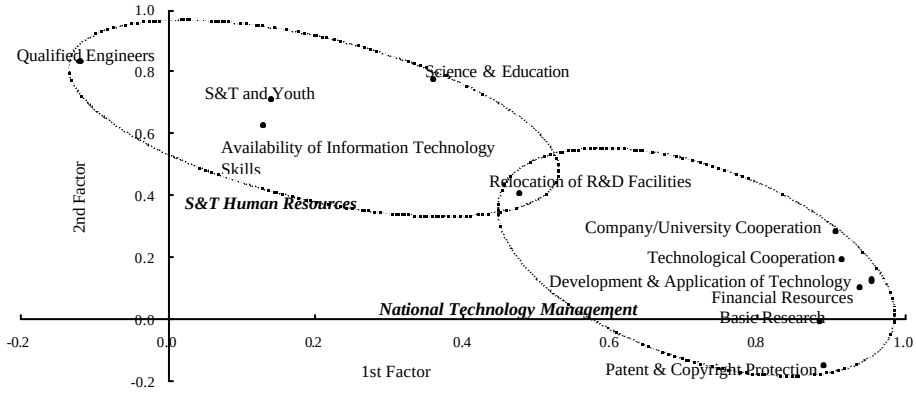

Figure 2. Factor Lodgings of the Soft Criteria

Needless to say, the criterion structure of the 2002 Yearbook is very similar to that of 2001. In addition, based on the above-mentioned analyses, we thought that the criterion structure obtained from the 2001 Yearbook could be a standard for all years from 1992 to 2002. The reasons are that the number of criteria has increased and that the reliability of each criterion has seemingly improved owing to the experience of those surveying and responding.

4 Trends of S&T World Competitiveness

First, we calculated "S&T World Competitiveness" using the IMD method, applied to the 33 countries that have no missing values. The calculation method was presumed, because its details seem to have never been published nor to have changed. Therefore, STWC calculated by us may differ from the value IMD would calculate by its own method. Then we calculated STWC by our own method, based on the above analyses. Because there was not a significant difference between the two methods, we decided thereafter to calculate each indicator using our method.

4.1 S&T World Competitiveness by the Presumed IMD Method

We presumed the IMD method to calculate STWC to be as follows:

$$C_j = k_h S x_{hij}/s_{hi} + k_s S x_{sij}/s_{si}, \quad (1)$$

where C_j is the "S&T World Competitiveness" of the country j,
x_{hij} or x_{sij} is the hard (h) or soft (s) criterion i of the country j,
s_{hi} or s_{si} is the standard deviation of the hard (h) or soft (s) criterion i, and
k_h and k_s are the coefficients of the hard and the soft criteria. Actually, $k_h = 1/15$ and $k_s = 1/11$ in the case of 2001 , which means that both hard and soft weights are equal.

The United States received the maximum value, which was adjusted to 100. The other countries were adjusted proportionately. The results are shown in the figure below.

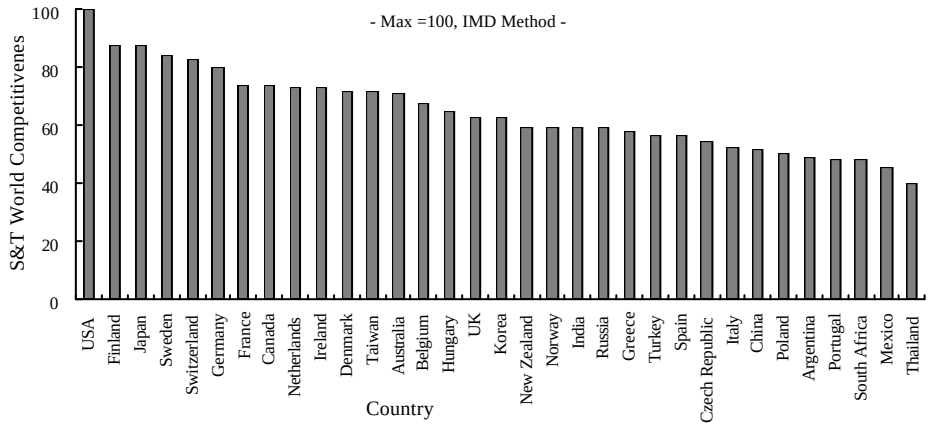

Figure 3. S&T World Competitiveness, IMD Method

As the figure shows, the U.S. has the greatest S&T World Competitiveness, followed by Finland and Japan, with approximately equal values. Sweden, Switzerland, and Germany comprise the third group, but the difference between the first and the second groups is greater than that of the second and the third. Based on our experience developing and analyzing the "General Indicator of S&T (GIST)" (Niwa and Tomizawa, 1996, 1998; Tomizawa and Niwa, 1996), we thought that Japanese competitiveness might be overestimated. Actually, we can find more statistics for the input and industry in the criteria list, and it suggests that such a judgment is not necessarily wrong.

4.2 S&T World Competitiveness by Our Modified Method

We modified the IMD method based on the results of the criteria analyses to calculate STWC as follows:

$$C_j = k_{hj} S x_{hij} / s_{hi} + k_{sj} S((x_{sij}-5)/s_{si}+5), \quad (2)$$

where C_j, x_{hij}, x_{sij}, s_{hi} and s_{si} have the same meanings as in formula (1).

$k_{hj} = 1/ n_{hj}$ and $k_{sj} = 1/ n_{sj}$, n_{hj} and n_{sj} are the numbers of hard and soft criteria used for country j.

Because we did not use the criteria of missing values, nhj and nsj vary across countries. Moreover, neither "Changes in Patents Granted to Residents (ChngPtn)" nor "Number of Patents in Force (PntFrc)" is adopted from the characteristics of

these criteria. Furthermore, we assumed that five must be the fixed value of neutrality for all respondents because it is the middle point of the continuum used for the questionnaire survey. Again, the United States got the maximum value, and it was adjusted to 100. The other countries were adjusted proportionately.

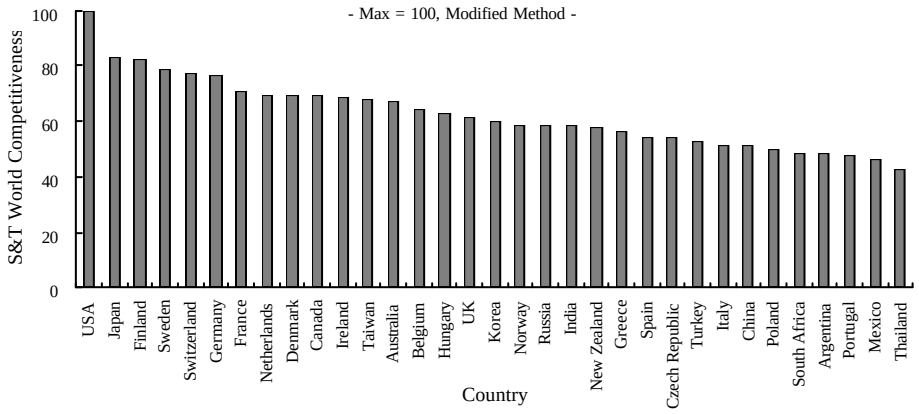

Figure 4. S&T World Competitiveness

We can find only slight differences between the figures; actually r = 0.994. However, the rankings of several countries are different, and the difference between the first and second groups in the second figure is slightly greater than in the first. We believe the second figure reflects more exactly the actual situation.

4.3 Time Trends of S&T World Competitiveness

We calculated STWC as follows:

$$C_{jt} = k_{hjt} S(x_{hijt} - \mu_{hit})/s_{hit} + k_{sjt} S(x_{sijt} - 5)/s_{sit}, \quad (3)$$

where C_{jt} is the "S&T World Competitiveness" of country j and year t,

x_{hijt} and x_{sijt} are the values of the hard (h) and soft (s) criterion i of country j and year t,

μ_{hit} and, μ_{sit}, and s_{hit} are the means and standard deviation of the hard (h) and soft (s) criterion i and year t respectively.

$k_{hjt} = 1/ n_{hjt}$ and $k_{sjt} = 1/ n_{sjt}$, n_{hjt} and n_{sjt} are the numbers of hard and soft criteria for country j and year t. They vary across countries and years, because we did not use missing values.

This formula indicates that competitiveness is a mean of the so-called STD values of the hard and soft criteria used by the IMD Yearbooks (IMD, 1986-2002). We then calculated competitiveness for each year.

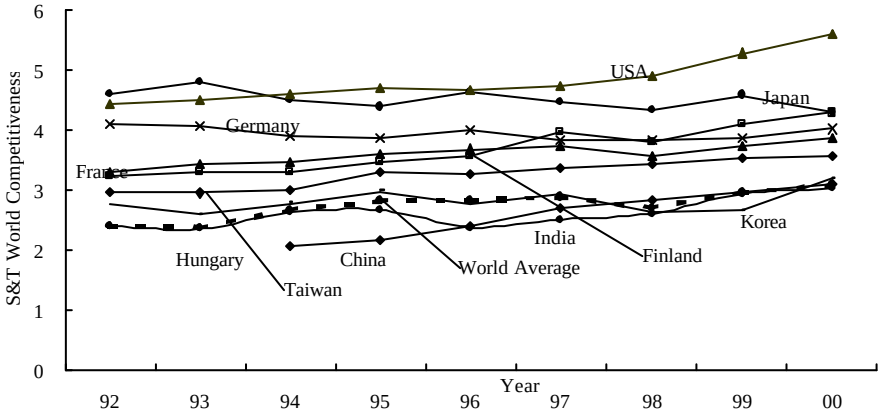

Figure 5. S&T World Competitiveness

Figure 5 shows the STWC time trends of the selected countries from 1992 to 2000. The period was chosen based on the total stability, that is, the number and balance of the criteria (See Tab. 1). The figure and our analysis show the following tendencies:

- Most of the selected countries have increasing tendencies.
- The STWC of the U.S. shows the largest increase among the selected countries. In particular, its growth ratio in the late 1990s is remarkable. Therefore, the gap between the U.S. and other countries has expanded.
- The STWC of Hungary is also remarkable, followed by that of Finland and China.
- Japan shows the greatest decreasing tendency, followed by Germany. Japan's lead position was lost to the U.S. in the mid-1990s, and other countries will catch up to Japan in the near future.
- India and Taiwan show increasing tendencies, following Hungary, Finland and China group.

5 Relationships Among the Related Indicators

Accordingly, we developed the following indicators:

1. S&T World Competitiveness
2. S&T Power

3. S&T Activity Density
4. National Technology Management
5. S&T Human Resources

For the calculation of the indicators, with the exception of "S&T World Competitiveness," we used the factor scores of the 33 countries that were the results of the factor analyses. The indicator "S&T World Competitiveness" is calculated as the summation of the other four indicators. We analyzed firstly the correlative relationships among the indicators, and secondly their relationships with GDP and population (see table 3).

Table 3. Relationships among the Related Indicators

	S&T World Competi-tiveness	S&T Power	S&T Activity Density	National Technology Management	S&T Human Resources
S&T World Competitiveness	1.000	0.648	0.846	0.883	0.404
S&T Power	0.648	1.000	0.401	0.326	-0.020
S&T Activity Density	0.846	0.401	1.000	0.791	0.121
National Technology Management	0.883	0.326	0.791	1.000	0.297
Human Resources	0.404	-0.020	0.121	0.297	1.000
GDP	0.616	0.962	0.330	0.336	-0.020
GDP(ppp)	0.465	0.878	0.158	0.198	-0.036
Population	-0.095	0.187	-0.242	-0.212	-0.003
GDP per capita	0.773	0.445	0.856	0.754	0.009
GDP(ppp) per capita	0.747	0.339	0.763	0.796	0.130

The correlation coefficients over 0.75 are underlined, except in the case of "S&T World Competitiveness." Among the indicators developed, "S&T World Competitiveness" has strong relationships with the other three component indicators, with the exception of "S&T Human Resources." Only one pair, "S&T Activity Density" and "National Technology Management," correlate strongly with each other, while "S&T Human Resources" is isolated from all other indicators. This implies that the fostering of S&T Human Resources will influence S&T activities in the long term. The table also shows that population is not related to the indicators that are related to S&T. On the contrary, GDP relates more strongly to "S&T Power" than to "S&T World Competitiveness," while GDP per capita also relates firstly to "S&T Activity Density" and secondly to "S&T World Competitiveness" and "National Technology Management." We should pay particular attention to the last relationships, because they imply that S&T activity density and national technology management strategy contribute to national economic development or growth.

Covariance Structural Analysis

We applied covariance structure analysis to the indicators. Figure 6 shows its result, that is, a structure among criteria. As fidelity functions we used general least square method and maximum likelihood method. The results of the analysis shows that the S&T activity density cannot directly contribute to the economic development, and the national technology management must lie between them. This result can be completely understood. In this case, the ?2 (df=1) is 17.323, and its probability is very close to 0.0000.

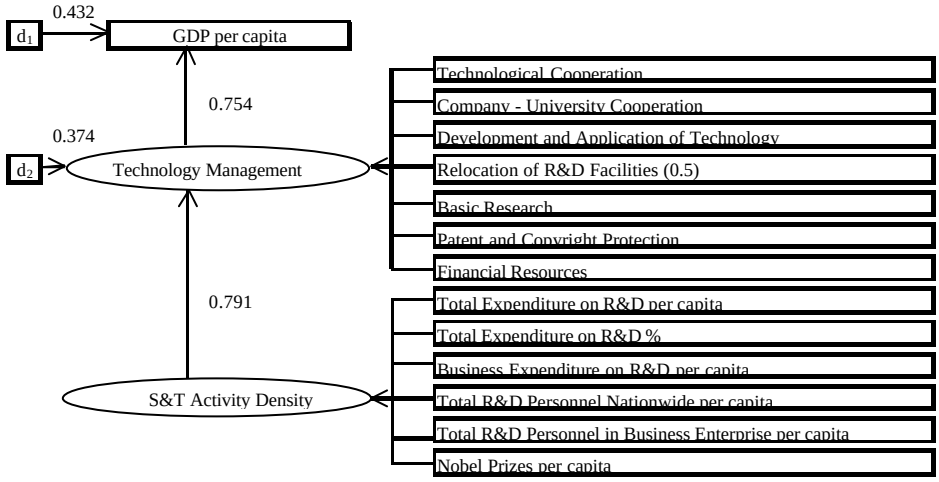

Figure 6. Structure of S&T World Competitiveness Indicators

6 Concluding Remarks

First of all, we express our gratitude for the World Competitiveness Yearbook published by the IMD, whose analyses are very useful. The publication has made people in the world recognize the necessity and usefulness of the measured data, and we think that this is a significant achievement. It has actually stimulated several countries with poor statistics to improve them. Furthermore, we used not only the results analyzed by the IMD but also the values of criteria as the material for our own analysis. Finally, the IMD has improved the criteria every year. Our analysis owes greatly to the efforts of the IMD in this respect.

However, we would like to point out some problems. To obtain a World Competitiveness ranking, it is self-evident that criteria with different characteristics, such as hard and soft criteria, will be summed up. However the differences between those characteristics must be analyzed before the summation. When we integrate a

large number of criteria, a structural analysis among them is necessary before the integration. Our analysis has clarified that the IMD's criteria concerning S&T actually belong to four statistically independent criteria clusters.

Second, the hard criteria might be too small in number. Certainly, it must be very difficult to collect criteria from so many countries for comparison. For instance, although we gathered twelve hard absolute criteria to integrate the S&T General Indicators, we focused on only five developed countries.

Third, the Yearbook adopts only one criterion for growth ratio type as mentioned above. We can calculate the growth rate type using only hard absolute criteria, but different aspects of competitiveness may become apparent using relative hard criteria. Adopting additional growth rate type criteria might be an improvement, although prior analysis is necessary.

Fourth, although the questionnaire survey respondents totalled more than 3,500 for the 2001 Yearbook, we understand that the return ratio in Japan was only about 13%, resulting in less than 150 responses (Kitamura, 2002). This suggests a problem of reliability. The IMD Yearbook lists a partner survey organization in each country, but this is insufficient. We would like to ask the IMD to increase the number of samples and respondents from each country.

Fifth, there are problems in the use of the results (Kitamura 2002). This problem might be limited to Japan, where only the ranking is emphasized. However, it is necessary to recognize the position of each country in the distribution (see figures 4 and 5). In addition, while the Japanese are apt to pay attention to the value of specific soft criterion, such as "Company-University Cooperation," they should also heed the trend of criteria clusters, such as "National Technology Management." It might be insufficient to use only a fragment of the content of the Yearbook and to ignore the original data.

Finally, we analyzed only the S&T sub-factor in this paper, because in Japan people are highly interested in S&T (Niwa & Kuwahara, 2002, 2005). It is easily possible to expand the analysis to all criteria comprising World Competitiveness. We think that such an analysis can contribute greatly to the overall structural understanding of global competitiveness. We are in the process of undertaking this task.

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