Technological Capability Monitoring Index, A New Composite Index for Measuring Technological Capabilities of Nations

Seyyed Habibollah Tabatabaeean[a], Reza Naghizadeh[b,1,] Arman Khaledia, Mohammad Naghizadeh[a]

a Department of Industrial Management, School of Management & Accounting, Allameh Tabataba'i University, Tehran, Iran
b Department of Information Technology Management, School of Economy and Management, Tarbiat Modares University, Tehran, Iran

Abstract

Considering the important role of technological capability in economic growth and increase in the welfare of the countries, the issue of technological capability monitoring has gained great importance in recent years. So far, various international models have been designed and introduced in relation to technological capability evaluation. Regarding the innate characteristics of composite indexes which involve some deficiencies; using the experiences of internationally accredited models, it is tried in this study to introduce a new composite index for technological capability monitoring in order to better evaluate the technological capabilities of countries from various aspects. Also, it is tried through provision of the logical weights resulting from the application of factor analysis to design a more practical index for various countries, particularly, those developing countries suffering from imbalanced development. In this study, 17 indicators were selected on the basis of a specific process from among 37 internationally important indicators regarding technological capability. Then, on the basis of factor analysis of the available data in relation to the selected indicators, the 17 indicators were placed in 3 aspects, and specific weights were assigned to the aspects and indicators by factor analysis. Finally, based on the combination of 17 indicators in 3 aspects, the composite index of technological capability monitoring was created. On the whole, the composite index of technological capability monitoring, adds new capabilities besides other international indexes to the issue of technological capability monitoring.

Keywords: Technological Capability, World Technological Capability Monitoring, Composite Index

1. Introduction

One of the basic and important components of economic growth and welfare of the world countries is their technological capability (Archibugi & Coco, 2004). Therefore, various countries of the world attempt to increase their technological capability level. Technological capability can be defined as the efficient use of technological knowledge for creation, application, publication, acceptance, and changing the present technologies (Kim, 1997). This concept does not only refer to the organized research and development(R & D) in developing countries, but also include concepts such as commercial exploitation of technology. In this regard, Kim (1997) considers the three aspects of technological capability as including production capability, investment capability, and innovation capability.

[1] Corresponding Author: Tel.:+982188615889; fax: +982188615890. E-mail: rezanaghizadeh@yahoo.com

The term technological capability has been used in many studies (Romijn, 1999). Although, these analyses were originally offered for firms, it was applied for industries and countries, too. Lall (1992) emphasized the three aspects of national technological capability in a survey. The points stressed by him include the followings.

- Capability of gathering sufficient financial resources and effective use of them;
- The skills not only include general trainings but also involve technical merits and project management; and
- What he considers as national technological attempts relates to variables such as research and development, patent, and technical personnel.

He, also, does not consider national technological capability as dependent upon domestic technological attempts; rather believes that some of it is resulted from the technology acquired from foreign countries through importing machinery and foreign direct investment. This discussion supports the new growth theory which states that small countries face problems for innovation, and depend on free commerce and movement toward international financial trends for solving their problems (Grossman & Helpman, 1991; Coe & Helpman, 1995).

Lall (1992) also distinguishes between technological capability and its economic impacts. He, also, relates these impacts to incentives which whom the economic agencies face due to the political and governmental decisions or the institutional system. Thus, technological and social capabilities must interact with each other for development.

As it was mentioned, the undeniable effects of technological capability on the economic growth and welfare of the countries have resulted in the especial attention to this issue in national and firm level. Certainly, in line with increasing the technological capability, the policy-makers and managers of the countries must have an appropriate and correct view of the condition of their and other countries' technological capabilities. Particularly, considering the globalization of technological attempts, having a true understating of the one's own and other countries technological capability is deemed necessary.

In this regard, three main characteristics for systematic collection of data related to countries' technological capability are mentioned (Arundel & Garrelfs, 1997; Archibugi, Denni, & Filippetti, 2009):

I. Theoretical analyses: the indices of innovation can result in the increase and expansion of awareness toward technological changes and theoretical tests of innovation.
II. The information source for governmental policy-making: policy-makers need to evaluate and compare their countries with other countries so that they can recognize the weaknesses and strengths of their countries, use technological opportunities, and finally, investigate the efficiency of policies.
III. As an entrance for firms strategies: managers use the innovation studies for better understanding the technological advances, particularly, for increasing their penetration in the competitive domestic and international markets. Data related to technological capability of the countries provide the countries with the opportunity to find out which company in a given country can develop and put its innovative activities into practice.

In this study, special attention has been given to creation of a new composite index considering various experiences in the area of technological capability monitoring. In recent years, extensive attempts have been made for technological capability evaluation of countries at the international level and different models have been devised for technological capability evaluation at the national level, such as the global competitiveness index of world economy forum, competitive industrial performance index by UNIDO, UNDP technology achievement index, knowledge economy index by World Bank, ARCO technological capability index, science and technology capacity index of Rand organization, and so on.

The composite index of technological capability monitoring which is presented in this article allows countries to compare themselves with other countries thereby implementing more appropriate policies. Various elements influence determination of technological capability of a country, among them an overall index can do the monitoring in a more simple way compared to various indices. In designing the technological capability monitoring index, some main points have been considered:

- The emphasis is on indicators which investigate more aspects of technological capability of a country.
- Usability for different countries regardless of the level of their development.
- Coverage of appropriate number of developed and developing countries.
- Consideration of logical weights for indicators.

The composite index of technological capability monitoring has tried to make a logical relationship between the number of countries and the indicators considered in the model. Regarding the point that the more the number of technological capability evaluation indicators, the lesser the number of countries whose scores can be calculated, the necessity for making a logical relationship between the number of indicators and countries is clear. Also, the given index, besides covering the needs of developed countries due to the provision of a logical structure in assigning weights to the indicators, provides the possibility for developing countries, which usually suffer from an imbalanced development, to gain a closer understanding of their position in global technological level.

The next part of this paper reviews the models related to technological capability evaluation considered in this study. In the third part, the indicators of monitoring are investigated. In the fourth section, the research methodology is introduced and in the fifth part, the composite index of technological capability monitoring is mentioned. Finally, in the sixth section, the ranking of the 70 countries of the world based on the composite index of technological capability monitoring are stated in three categories of large, middle, and small economies.

2. A review of the models of technological capability monitoring

Various models and frameworks have been considered in relation to technological capability monitoring in the world. In this regard, in the world technological capability monitoring of 2009, it is tried to investigate some of the most important models in order to achieve a more comprehensive composite index using their experiences. The models under study include the global competitiveness index of world economy forum, UNIDO index of competitive industrial performance, UNDP technology achievement index, World Bank knowledge economy index, ARCO technological capability index, science and technological capacity index of Rand organization, and analytical framework model of evaluation of technological capability level, each of which are briefly introduced in this section.

2.1. The global competitiveness index of world economy forum

The global competitiveness index is annually published by the world economy forum. This model does not exclusively evaluate technological capability. In the version of 2008 – 2009, this model includes 12 pillars which are divided into 3 aspects. In Figure 1, the 12 pillars are identified in 3 aspects (WEF, 2008).

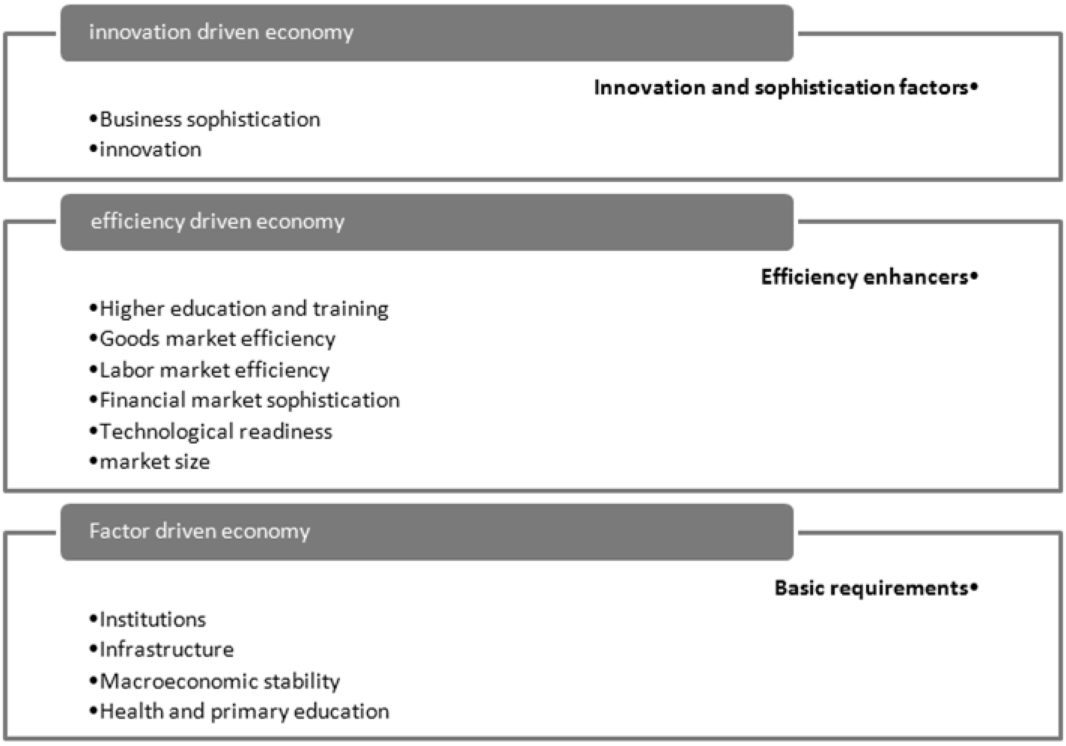

Figure1. Aspects of Competitiveness (WEF, 2008)

One characteristic of this model is primary classification of the countries according to one or two specific indicators and based on this classification, it evaluates the countries. The global competitiveness index in 2001 (WEF, 2001) classifies the countries into two categories of marginal and central countries based on the patent indicator. Also, WEF, in the report of 2008 – 2009 (WEF, 2008), based on GDP and the proportion of the export of primary goods to total export (the complementary indicator) categorizes the countries into three groups of efficiency-driven, innovation-driven, and factor-driven. In this model, equal weighing approach is used for assigning weights to indicators. Considering the weights of the aspects, weights are assigned according to the category of the countries and degree of importance of each of those aspects for that category. Table 1 indicates the weights assigned to every aspect regarding the category of each country.

Table1. The Weights of Factors in Each Group (WEF, 2008)

Pillar group	Factor driven stage(%)	efficiency driven stage(%)	innovation driven stage(%)
Basic requirements	60	40	20

Efficiency enhancers	35	50	50
Innovation and sophistication factors	5	10	30

It should be mentioned that in this model, the two pillars of innovation and technological readiness relate greatly to technological capability and can be analyzed separately. One interesting point about this model is the simultaneous use of hard and survey data.

2.2. science and technological capacity index of Rand organization

This index has been designed by Wagner and his colleagues (Wagner, Horlings, and Dutta, 2004) in Rand organization. In 2001, based on 8 indicators, 76 countries of the world were investigated with respect to their science and technology capacity (Wagner et al, 2004). Finally, the 8 indicators, as can be seen in Figure 2, were placed in 3 aspects of embedded knowledge, resources, and enabling factors.

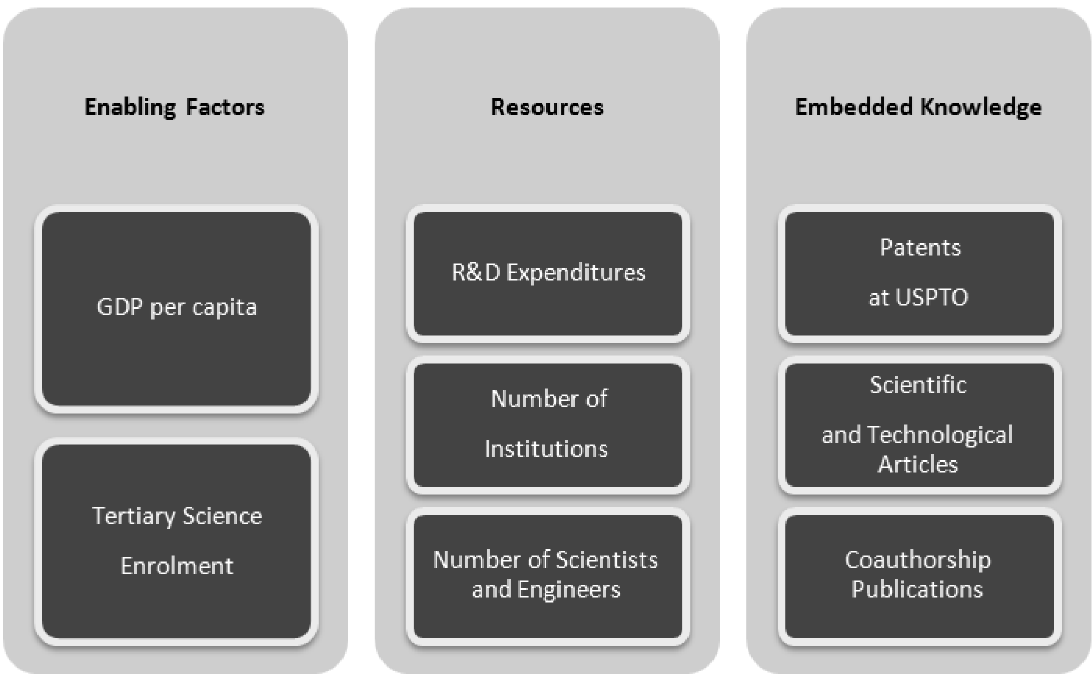

Figure 2. science and technological capacity index (Wagner et al, 2004)

In this model, equal weights are assigned to the indicators of each aspect, but the weight of aspect of resources is twice as much as two other aspects. At the end, the 76 countries investigated were placed in 4 categories of lagging, developing, proficient, and advanced countries based on the ranking resulting from the model.

2.3. World Bank knowledge economy index

The index of knowledge economy has been devised by the World Bank. The World Bank, through a program called knowledge for development, has designed a model entitled as methodology of knowledge assessment for identifying the weaknesses and strengths of countries in line with movement toward knowledge economy, and updates it every year. Based on the report of 2009, this methodology involves 109 qualitative (survey) and quantitative variables for 149 countries (World Bank, 2009). This methodology is an internet-based and interactional instrument (World Bank, 2008). It depicts the overall performance of economy and 4 bases of knowledge economy framework.

The bases of this methodology include educated and skilled workforce, efficient innovation system, appropriate information infrastructures, institutional and economic incentives regimes.

In the methodology of evaluation of the position of knowledge economy in a country and indicating its results, 6 different models of basic scorecards, knowledge economy index and knowledge index, custom scorecards, over time comparisons, cross country comparison, and world map are used. However, the most important model is the base score card which includes 14 standard variables (2 variables of performance and 12 variables of knowledge, these 12 variables are placed in 4 categories in the subsets of knowledge economy) (World Bank, 2008).

2.4. ARCO technological capability index

This model has been developed and applied by Archibugi and coco(2004) for evaluation of the level of technological capability of a vast number of countries in 2004. This model has been founded on the basis of previous models, particularly UNDP technology achievement index and industrial development scoreboard (UNIDO, 2003). This model emphasizes simultaneous evaluation of tacit and explicit knowledge within the framework of three aspects of innovative activities, technological infrastructures, and human capital. It should be mentioned that evaluation based on ARCO model has been conducted for 162 countries of the world on the basis of 8 indicators in 3 aspects (Archibugi & Coco, 2004). In this model, aspects and indicators have identical importance, and equal weights have been assigned to all aspects and indicators within each aspect.

2.5. UNDP index of technology achievement

The index of technology achievement has been created by Desai et al.(2002), and has been mentioned in human development report of 2001 (UNDP, 2001).

In this model, 4 aspects have been investigated for technology achievement and each of these aspects includes 2 indicators. The aspects of this model are technology creation, diffusion of new innovation, diffusion of old innovation, and human skills. Equal weights have been assigned to aspects and indicators of each aspect (UNDP, 2001).

The interesting point is that in the studies conducted by Arcelus, Sharma, and Srinivasan(2005) on the relationship between the index of technology achievement and human development index, it was found out that these two indices indicate the validity of similar information and thus similar ranking of countries. Also, both indices measure the same level of economic and social welfare, and the index of technology achievement does not add anything to human development index.

2.6. The composite index of competitive industrial performance

During past years, United Nation's industrial development organization has developed the composite index of competitive industrial performance. This index helps to evaluate the industrial performance of the countries in global economy. The aim of this index is directly measuring the capabilities of the countries in producing and exporting competitive goods. UNIDO, for the first time, published this index in 2002 – 2003 report of industrial development and in that year, evaluated 78 countries whose information related to these indicators was available. However, UNIDO added 2 indicators to the total composite index and managed to increase the number of countries to 93. The competitive industrial performance index of 2009 follows the indicators offered in 2004, but the number of countries has been increased up to 122 (UNIDO, 2002, 2004, 2009). Table 2 presents the aspects and indicators of the competitive industrial performance index in 2009.

Table2. Competitive Industrial Performance Index of 2009 Report (UNIDO, 2009)

competitive industrial performance index	Aspects	Indicators
	Industrial capacity	manufacturing value added (MVA) per capita
	Manufactured export capacity	Manufactured exports per capita
	Industrialization intensity	the share of medium- and high-technology activities in MVA
		the share of manufacturing in GDP
	Export quality	the share of manufactured exports in total exports
		the share of medium- and high-technology products in total exports

2.7. The analytical framework model of evaluation of technological capability level

In this model, which as used by authors of this article in evaluation of Iran's level of technological capability in 2008, based on Lall's (1992) approach, three factors of incentives, capabilities, and institutional context are utilized for evaluation of the level of technology of the countries. This model is a combination of quantitative indicators and qualitative analyses.

This model emphasizes that incentives are, in some way or another, creators of technological capabilities within an institutional context; however, this relationship is not linear, rather in a nonlinear manner, the level of capability influences the incentives and institutional context.

The main reason of using such an analytical framework for more comprehensive evaluation of the level of countries' technological capability is the emphasis upon the necessity of a comprehensive consideration of technology development and avoiding from common views. The idea and thought behind this framework, which is the comprehensive view of technology development at national level, is more important than correctly placing each of the indicators in the components of analytical framework.

In this analytical framework, technological capability are located at the center of the model which itself is composed of three sections of physical investments, human resources, and technological efforts. These capabilities are affected by incentives, and all of them are integrated in an institutional context consisting of organizations, regulations, norms, etc. (Lall, 1992).

3. Categorization of indicators to be evaluated

Investigating the mentioned models, some of the indicators related to World development indicators(World Bank-B, 2009), and some indicators related to the reports of United Nations, such as world investment report (UNCTAD, 2008) 37 indicators which are directly related to technological capability were identified. These indicators are presented in 10 categories in Table 3. Of course, 12 out of 37 indicators are related to survey indicators of global competiveness report of world economy forum which are not used due to their inherent difference with other indicators of the categorization of Table 3 and the set of indicators selected for evaluation of technological capability.

Table 3. Categorization of indicators in Models of Technological Capability Evaluation

	Indicators Category	GCR[2]	RAND[3]	KE[4]	ARCO[5]	TAI[6]	CIP[7]	Analytical Framework
1	Indicators Related To Patent	✓	✓	✓	✓	✓		✓
2	Indicators Related To Higher Education	✓		✓	✓	✓		✓
3	Indicators Related To Computer And Internet	✓		✓	✓			✓
4	Indicators Related To Telephone And Internet	✓		✓	✓	✓		✓
5	Indicators Related To The Share Of Medium-And High-Technology Products In Total Exports And Manufacturing Added Value	✓				✓	✓	
6	Indicators Related To Electricity Consumption				✓	✓		
7	Indicators Related To Mean Years Of Schooling And Tertiary Enrollment In Science	✓		✓	✓	✓		✓
8	Science Journal Article		✓	✓	✓			✓
9	Indicators Related To Gdp	✓	✓	✓				✓
10	Indicators Related To Research And Development		✓	✓				✓

4. Research Methodology

[2] WEF, 2008
[3] RAND, 2001
[4] World Bank, 2009
[5] Archibugi & Coco, 2004
[6] UNDP, 2001
[7] UNIDO, 2009

As it as mentioned in previous sections of the paper, various models exist for evaluation of technological capability. In addition, various indicators are available for evaluation of different aspects of technological capability, investigation of which is not possible at the time being. In creation of a composite index for evaluation of technological capability the limitation of countries' data, particularly in the case of developing and less developed countries, must be considered besides evaluation of various indicators which measure different aspects of technology. Creating balance among the indicators to be evaluated and countries which have the required data is very important. In the model of world technological capability monitoring it was tried to take this point into consideration. In this model, the index was attempted to be evaluated at least for 60 countries. From among 37 indicators for evaluation of technological capability 17 were selected through screening for creation of the composite index of technological capability monitoring. One of the distinguishing features of the present study from previous studies is the use of factor analysis with Varimax rotation method for achieving an appropriate model and framework of technological capability evaluation based of the available indicators. Finally, the technological capability monitoring index was calculated for 70 countries of the world. In general, the research steps are showed in Figure 3.

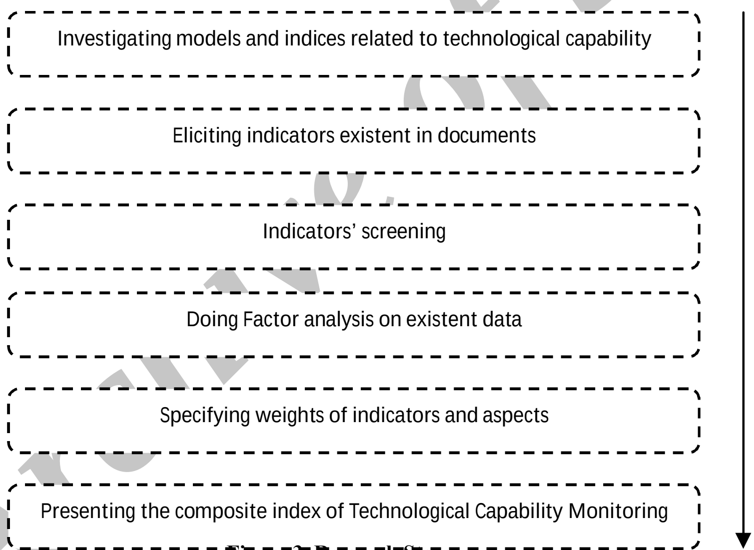

Figure 3: Research Steps

4.1. Screening the indicators

Screening of the indicators from among a large number of indicators is a very important task in evaluation of technological capability. Generally, this process is conducted through experts' opinions in international models, and assigning weights is performed on the basis of a subjective judgment process (Moon & Lee, 2005). In this model, for screening the models, it was tried to utilize a 6-step process so that besides evaluating various aspects of technological capability, technological capability of more countries, especially developing ones, can be measured. In this regard, the six following stages were followed in order to screen the indicators and achieve the final indices.

i. The indicators must be included in one of accredited international models or reports.

ii. Their data must be available since 2005.
iii. They must cover a sufficient number of countries (The emphasis is at least on 60 countries).
iv. They must be approved by the panel of experts of the project team.
v. They must evaluate various aspects of technology (according to experts' opinion).
vi. They must be collectable in case of developing countries, as far as possible.

Based on the above mentioned points, and the fact that some of the indicators of WEF are not considered in the present model due to being qualitative, 17 indicators were selected for final evaluation. Table 4 presents the selected countries together with their characteristics. Manner of defining the indicators and collecting the data is in accordance with a source from which the amount of indicators has been extracted. Also, it is worth mentioning that panel of experts includes experts who have experience and expertise in the evaluation of technological capability of the countries.

Table4. Final indicators of the Model of World Technological Capability Monitoring with a brief description of their Characteristics

Indicators	A brief description of indicators' characteristics	Data Resources
Gross tertiary education enrollment rate 2007	Since human skills play an important role in development of technology and increasing the level of technological capability, this indicator is designed for the purpose of evaluating the capability level of human resource. Higher education is very important in today's knowledge-based economy for exploiting, using, and accordance with modern technologies.	World Development Indicators (World Bank-B 2009)
Electric power consumption per capita (kWh) 2006	This indicator indicates part of physical infrastructures of the country for technological and industrial development. It correlates with the level of economical growth, whether compared with each other or in different development stages of a country. This indicator is especially important because it is one of the prerequisites of modern technology (UNDP, 2001).	World Development Indicators (World Bank-B 2009)
Scientific and Technical journal articles per capita 2005	This indicator indicates the amount of the output of active researchers' and experts' efforts. It also shows the approximate amount of the publication of science and technology in a country. Scientific papers are one of the important sources of explicit knowledge (Archibugi & Coco, 2004).	World Development Indicators (World Bank-B 2009)
Internet users per 100 people 2007	Internet is a fundamental infrastructure not only for commercial purposes, but also for the acquisition of knowledge (Archibugi & Coco, 2004); thus, it plays a major role in evaluating the necessary infrastructures of a country.	World Development Indicators (World Bank-B 2009)
Fixed line and Mobile cellular Subscriptions per 100 people 2007	Phone lines and mobiles other than being a major component of civil life, are infrastructures for commercial purposes. Also, this indicator is one of the important tools for measuring development of old technologies (UNDP, 2001).	World Development Indicators (World Bank-B 2009)
GDP per capita 2007	The amount of necessary infrastructures for supporting economy and research activities is measured by this index. Also, this index can show economic position of a country. According to Furman, Porter and Stern.(2002), GDP is not only measured for all countries, but also indirectly evaluates accumulation of knowledge in economies (Chinaprayoon, 2007).	Global competitiveness report (World Bank-B 2009)
Researchers in R&D per million people (2000-2006)	This indicator shows the ability of the population of a country in using the present and related knowledge for solving problems, improving economic condition and conducting research.	World Development Indicators (World Bank-B 2009)
Education expenditure(% of GNI) 2007	Considering the important role of education in development of the countries, the amount of expenditure in education is the indicator of countries' efforts for development of human infrastructures of	World Development Indicators (World Bank-B 2009)

	technology. Thus, evaluation of this indicator can indicate the necessary infrastructures for development of technology of countries.	
Adult literacy rate 1995-2005 (% aged 15 and above)	Education and acquisition of knowledge and general reasoning skills is one of the main bases of development of every country in the area of technology. Also, increasing the level of knowledge increases the ability to accept new ideas and changes the views toward work and society.	Human Development Report (UNDP, 2007)
PCs per 100 people (Access and use) 2007	This indicator is somehow related to infrastructures of information and communication technology in every country. It is considered as one of the inputs of innovation and entrepreneurship in evaluation of countries.	World Development Indicators (World Bank-B 2009)
Patent granted at USPTO per million 2007	Most pioneering studies on determination of innovation use this indicator as the indicator of innovation (Porter & Stern, 2000; Furman et al., 2002; Ulku, 2004; Chinaprayoon, 2007)	U.S.Patent office (2008)
National granted patent per million(resident patent) 2007	Since due to some reasons (political, economic, social), it is possible for U.S.Patent office not to provide a clear picture of innovation in every country, this indicator is utilized.	World Development Indicators (World Bank-B 2009)
Share of high/medium technology production in manufacturing value added (%total value added) 2005	The share of the value added of high-tech and medium industries in the total added value of every country shows its scientific and technological development. Therefore, investigation of this indicator proves important.	Industrial Development Report (UNIDO, 2009)
R&D expenditure on GDP(2000-2006)	This indicator is a direct criterion for measuring the amount of investment on research and development activities. It also shows the importance of these activities in every country. While other factors are stressed, the ratio of research and development expenditure to GDP is still the most effective indicator of investigating innovation in developing countries (Chinaprayoon, 2007).	World Development Indicators (World Bank-B 2009)
High technology export (% of manufactured export) 2007	This indicator shows the ability of national economic system of a country for competition in international markets of hi-tech industries. Hi-tech exports show the technological changes of a country (Chinaprayoon, 2007).	World Development Indicators (World Bank-B 2009)
Inward FDI Stock per capita 2007	This indicator measures the degree of economic freedom for a country.	World investment report (UNCTAD, 2008)
Outward FDI Stock per capita 2007	This indicator measures technological capability of a country regarding expansion of technology. It also evaluates the capability of country in transferring technology to other countries.	World investment report (UNCTAD, 2008)

These indicators can be evaluated for 70 countries of the world. In the case of countries which lack 2 items of the indicators, it has been tried to use the prediction of that index.

4.2. Data collection and normalization

Basically, one of the most important processes of research is data collection. Since later analyses are conducted based on the data, valid data must be collected in this stage. Therefore, in this study, international reports which are annually published by the United Nation, World Bank, World Economic forum, and U.S. Patent Office were used for collecting the required data.

In addition, considering the fact that the indicators of the model had different measurement units, they were first normalized by Formula 1 to be combined.

$$= \frac{X \quad - X}{\sigma}$$

Formula 1. Normalization of indicators

In this formula, Y_{ij} is the normalized form of indicator j for country i.

- X_{ij} is the real amount of indicator j for country i.
- X_j is the mean of indicator j for all countries.
- σ is the standard deviation of index j for all countries.

In the composite index of 2009 technological capability monitoring, 70 countries from various regions were evaluated and monitored. Figure 4 shows the share of each region of the countries investigated.

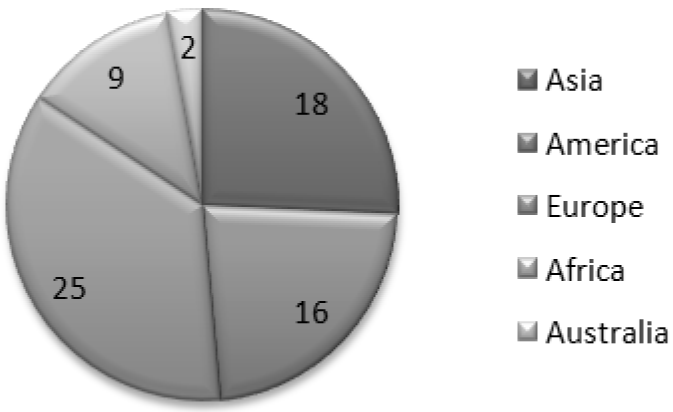

Figure 4. The Share of Different Regions of the Countries Investigated In World Technological Capability Monitoring Report, 2009

Furthermore, in world technological capability monitoring, countries are divided into three groups of large, middle, and small economy based on their GDP. Large economies have GDP over 1000 milliard Dollars; those with medium economy have GDP between 200 and 1000 Millard Dollars and the GDP of small economies is below 200 milliard Dollars. The distribution of countries based on this categorization is presented in Figure 5.

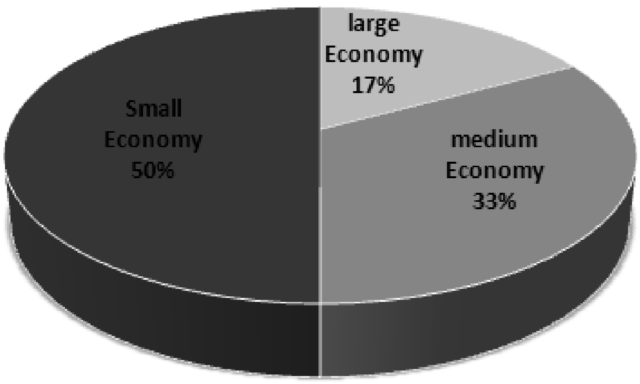

Figure 5. The Share of Various Economies in World Technological Capability Monitoring, 2009

4.3. Factor Analysis

During recent years, many attempts have been made for investigation of various approaches of assigning weights to indicators of a composite index such as Data Envelopment Analysis, AHP, and subjective judgment method. In this research, due to its unique advantages, factor analysis has been utilized for assigning weights and categorizing indicators. Some advantages of factor analysis for creating composite indices in the area of technological capability include:

i. Through factor analysis in this study, the fundamental structure of a rather large collection of variables can be achieved.
ii. In the factor analysis used in this study, no primary theory is assumed and the initial hypothesis is that every variable may have a relationship with a factor. Hence, interference of researchers' hypotheses in ranking the countries is minimized.
iii. The final ranking with high correlation can be evaluated through few indicators that really indicate an aspect with high weights.
iv. This method categorizes indicators in two different sets, none of other methods enjoy this capability (Nardo, Saisana, Saltelli, Tarantola, 2005; OECD, 2008)

In this regard, factor analysis is utilized for assigning weights and categorizing indicators in this study. Various models are available for conducting factor analysis such as Principal components analysis, Canonical factor analysis, Common factor analysis, etc. (Kline, 2000). In this research, considering the characteristics of principal component analysis and emphases of various international reports (Nardo et al, 2005; OECD, 2008) on the appropriate method of creating a composite index, principal component analysis was utilized. Also, various models exist for rotation of factor such as varimax, quartimax, equimax, the aim of all of which is achieving a simple and understandable pattern about the factor loading of different variables (Nardo et al, 2005). Since varimax rotation method is one of the most common methods (OECD, 2008) and most researchers believe that it is the most efficient method (Kline, 1994), varimax rotation method was used in this study. in this method, the rotated factors are uncorrelated and the ability of creating the original correlation matrix is equal with the initial factor analysis. The purpose of varimax is to maximize the sum of squared loadings variances on the columns of factorial matrix (Kline, 1994; Kaiser, 1958).

In addition, the amount of Kaiser-Meyer-Olkin test for the data calculated in this study is 0.853. According to Norusis (1985), the amount of Kaiser-Meyer-Olkin test over 0.7 indicates the appropriateness of data for factor analysis (De Vaus, 2002). Thus, 0.853 of Kaiser-Meyer-Olkin test shows the appropriateness of data for factor analysis. The output of SPSS for Kaiser-Meyer-Olkin test is presented in Figure 6.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.853
Bartlett's Test of Sphericity	Approx. Chi-Square	1.374E3
	Df	136
	Sig.	.000

Figure 6. The Amount of Kaiser-Meyer-Olkin and Bartlet Test on the Basis of SPSS

The total number of indicators is 17 which, after factor analysis, were placed in three groups with differing factor loadings. Table 5 shows the factor loadings of each of the aspects.

Table5. The Extracted Weight of Factor Analysis

Factor	1	2	3
Weights	0.50	0.29	0.21

The given aspects of this study obtained from factor analysis were named as technology development infrastructures, innovation capability, and investment quality, respectively. Regarding the discussion of scaling in factor analysis method, factor loadings are used as the importance coefficient of indicators for weighting the indicators. The results of rotated matrix of indicators in factor analysis are presented in Table 6.

Table6. The Total Value of Variance Stated by Fcators

Indicators	Component		
	1	**2**	3
Gross tertiary education enrollment rate 2007	0.8540416	0.2293397	**0.009**
Electric power consumption per capita (kWh) 2006	0.792889	0.3744285	**0.173**
Scientific and Technical journal articles per capita 2005	0.7891734	0.4140779	**0.216**
Internet users per 100 people 2007	0.776637	0.4146172	**0.309**
Fixed line and Mobile cellular Subscriptions per 100 people 2007	0.7685983	0.1331873	**0.404**
GDP per capita 2007	0.767554	0.3647055	**0.364**

Researchers in R&D per million people (2000-2006)	0.7618131	0.5287538	**0.163**
Education expenditure(% of GNI) 2007	0.6971296	-0.0917403	**-0.035**
Adult literacy rate 1995-2005 (% aged 15 and above)	0.6780738	0.1113867	**0.179**
PCs per 100 people(Access and use) 2007	0.6623343	0.4551015	**0.474**
Patent granted at USPTO per million 2007	0.4448916	0.7617162	**0.077**
National granted patent per million(resident patent) 2007	0.1719884	0.7581274	**-0.188**
Share of high/medium technology production in manufacturing value added (%total value added) 2005	0.2570859	0.7561444	**0.177**
R&D expenditure on GDP (2000-2006)	0.6142832	0.6609052	**0.083**
High technology export (% of manufactured export) 2007	-0.0814433	0.6389343	**0.329**
Inward FDI Stock per capita 2007	0.1844323	0.0426696	**0.938**
Outward FDI Stock per capita 2007	0.2435784	0.1089287	**0.923**

Based on the weighing conducted in factor analysis and the factorial classes produced, the composite index of technological capability monitoring is achieved. This index is discussed in the following.

5. composite index of technological capability monitoring

The index of technological capability monitoring is a composite index which has been designed for helping policy-makers to take appropriate science and technology policies. The composite index of technological capability monitoring enables countries to compare themselves with other countries thereby implementing more appropriate strategies. Various factors affect determination of technological capability of a country among which a general index can perform this monitoring in a simple manner compared with different indicators.

As it is observed in Table 7, the composite index of technological capability has been defined in terms of three main aspects of the technology development infrastructures, innovation capability, and investment quality. The aspect of technology development infrastructure is composed of 10 indicators each of which have their specific weights. The index of technology development infrastructure mainly consists of indicators related to human skills, information and communication technology together with two per capita indicators of GDP and electricity.

Table7. Aspects and Weights of Indicators

Aspect	Indicator	Weights
Technology development infrastructure (0.5)	Gross tertiary education enrollment rate 2007	**0.8540416**
	Electric power consumption per capita kWh 2006	**0.792889**
	Scientific and Technical journal articles per capita 2005	**0.7891734**
	Internet users per 100 people 2007	**0.776637**
	Fixed line and Mobile cellular Subscriptions per 100 people 2007	**0.7685983**
	GDP per capita 2007	**0.767554**
	Researchers in R&D per million people (2000-2006)	**0.7618131**
	Education expenditure(% of GNI) 2007	**0.6971296**
	Adult literacy rate 1995-2005 (% aged 15 and above)	**0.6780738**
	PCs per 100 people(Access and use) 2007	**0.6623343**
Innovation capabilities (0.29)	Patent granted at USPTO per million 2007	**0.7617162**
	National granted patent per million(resident patent) 2007	**0.7581274**
	Share of high/medium technology production in manufacturing value added (%total value added) 2005	**0.7561444**
	R&D expenditure on GDP(2000-2006)	**0.6609052**
	High technology export (% of manufactured export) 2007	**0.6389343**
Investment quality (0.21)	Inward FDI Stock per capita 2007	**0.938**
	Outward FDI Stock per capita 2007	**0.923**

As you can see in Table 6, the weights assigned to the aspects of the composite index of technological capability reveal the great importance of technology infrastructure relative to two other aspects. This aspect, with a weight of 0.5, enjoys especial importance. Also, the second aspect called as innovation capability is a little more important than investment quality aspect.

The aspect of innovation capability consists of 5 indicators which includes indicators of patent, hi-tech industries, the share of research and development expenditures. In the indicators of innovation capability the point should be considered that these indicators evaluate innovation capability less for the sectors in which the implicit knowledge is more. Also, in the aspect of investment quality, the amount of inward and outward foreign investment which is representative of a countries power in attracting foreign investments and investing in other countries is presented. This aspect also depicts the ability of a country in transferring and attracting technologies.

What is evident in these three aspects is the logical movement from infrastructures toward investment markets to be representative of the cycle of idea to market in the area of technology to a great extent.

6. Ranking of the countries

70 countries were evaluated based on 2009 world technological capability monitoring index. For the purpose of ranking the countries, first they, based on their GDP, were divided into three categories of large, middle, and small economy. The reason for this classification is difference in the economic condition of the countries. Generally, the countries in large economy group are the countries with a rather high population the ranking of which are certainly declined by per capita indicators. In order to solve this problem that is often observed in the composite international indices, the categorization was performed on the basis of GDP. Also, the fact should be mentioned that due to the accumulation of capital in these countries, some especial capabilities for development of modern and expensive technologies exist in these countries.

As it is shown in Table 8, among the countries with large economy, the U.S. is placed in the top position, and Japan, Canada, and England are in the subsequent ranks, respectively. Also, among the countries with large economy, China and India are placed in the last positions. It should be pointed out that the countries which are categorized in the group of large economy possess especial capabilities in creation and exploitation of modern technologies. Of course, these countries have more population; therefore, the per capita indicators decline in the case of some countries such as Russia, China, and India and this influences their rankings in composite indices. This problem can be clearly observed in the composite indices provided in the international models that causes the capabilities of countries like China and Russia to be underestimated in comparison to smaller countries. It has been tried in this model to decrease the degree of this problem by categorizing the countries into three above-mentioned groups.

Among the countries with middle economy, which can be observed in Table 8, Sweden, Finland, and Norway are in the top positions. Among the 23 countries of this group, South Korea, Netherlands, Australia, and Mexico have higher GDP. In this group, countries are classified into two groups of innovative countries follower of superior economies, and adaptive countries with average and modern technologies. Portugal is the last county of the innovative follower group among the countries with medium economy.

35 countries are categorized in the group of countries with small economy. Among them, three first ranking countries, that is, Singapore, New Zealand, and Israel possess high technological capabilities. Also, Slovenia, Estonia, Hungary, Czech Republic, Slovak Republic are considered as innovative follower countries in the field of technology and possess considerable technological capabilities in some sectors. At the last position among these countries are countries such as Senegal, Bangladesh, and Cameron which are regarded as retarded countries in the area of technological capabilities.

Table 8. Classification of countries on the Basis of the Ranking of Technological Capability Monitoring Index in Large, medium, and Small Economies

Rank	Large Economy	GDP	Score	Rank	Medium Economy	GDP	Score	Rank	Small Economy	GDP	Score
1	United States	13840	6.49408	13	Sweden	455.3	7.74788	36	Singapore	161.3	**5.17045**
2	Japan	4384	5.154904	14	Finland	245	7.407825	37	New Zealand	128.1	**3.90784**
3	Canada	1432	5.030038	15	Norway	391.5	7.258003	38	Israel	161.9	**3.2826**
4	United Kingdom	2773	4.508399	16	Switzerland	423.9	6.286367	39	Slovenia	46.08	**2.44404**
5	Germany	3322	4.176264	17	Denmark	311.9	6.092004	40	Estonia	21.28	**1.89056**
6	France	2560	3.577544	18	Korea	957.1	5.50377	41	Hungary	138.4	**1.26836**
7	Italy	2105	2.050843	19	Netherlands	768.7	4.829689	42	Czech	175.3	**0.84851**

									Republic		
8	Spain	1439	1.638519	20	Hong Kong SAR	206.7	4.588777	43	Slovak Republic	74.99	**0.40893**
9	Russia	1286	-0.08567	21	Ireland	258.6	4.351108	44	Malaysia	186.5	**-0.15738**
10	Brazil	1314	-2.05829	22	Australia	908.8	3.948218	45	Bulgaria	39.61	**-0.87304**
11	China	3251	-2.54671	23	Austria	373.9	3.666702	46	Romania	166	**-1.50399**
12	India	1099	-4.50977	24	Belgium	453.6	3.499454	47	Chile	163.8	**-1.50755**
				25	Greece	314.6	0.714348	48	Costa Rica	26.24	**-1.93822**
				26	Portugal	223.3	0.558457	49	Jordan	16.01	**-1.96269**
				27	Poland	420.3	-0.00972	50	Uruguay	22.95	**-2.22873**
				28	Argentina	260	-1.2413	51	Tunisia	35.01	**-2.25595**
				29	Thailand	245.7	-1.27971	52	Jamaica	11.21	**-2.32953**
				30	Mexico	893.4	-1.76659	53	Colombia	171.6	**-2.44188**
				31	Venezuela	236.4	-2.04454	54	Panama	19.74	**-2.44255**
				32	Iran	294.1	-2.23303	55	Philippines	144.1	**-2.84108**
				33	Turkey	663.4	-2.46112	56	Bolivia	13.19	**-3.19084**
				34	South Africa	282.6	-2.55584	57	Peru	109.1	**-3.41193**
				35	Indonesia	432.9	-4.41569	58	Egypt	127.9	**-3.45307**
								59	Morocco	73.43	**-3.60665**
								60	Algeria	131.6	**-3.82151**
								61	Vietnam	70.02	**-3.84037**
								62	Ecuador	44.18	**-3.9883**
								63	Kenya	29.3	**-4.13483**
								64	Syria	37.76	**-4.31931**
								65	Guatemala	33.69	**-4.40271**
								66	Sri Lanka	30.01	**-4.45019**
								67	Nicaragua	5.723	**-4.6278**
								68	Senegal	11.12	**-5.18702**
								69	Bangladesh	72.42	**-5.35523**
								70	Cameroon	20.65	**-5.40887**

7. Conclusion

Composite indices in the field of technological capability monitoring can provide a general picture from technological capability of various countries for more accurate and specialized investigation. This group of indices can aid policy-makers, agencies, scientists, and theoreticians. Nevertheless, these indices have some deficiencies that must be considered. Some of the most important of them include:

i. Limitation of data for different countries, especially developing and less developed countries.
ii. Logical relationship between the number of countries to be studies and number of indicators which result in removing some countries and some indicators.
iii. Inability in measuring variety of aspects of technological capability due to the limitation of data.
iv. Inability in completely measuring the implicit aspects of technological capability due to limitation of quantitative indicators.

The technological capability monitoring index like other composite indices of this area suffers from deficiencies, but what has been attempted to take into consideration in this index is assigning more logical weights on the basis of statistical methods, paying special attention to developing countries, considering idea to market chain in development of technology, and offering a composite and international index for the first time on the part of developing countries. This report, associated with other international models of technological capability monitoring, can be influential in policies of science and technology in all countries of the world, regardless of the level of their development. It is hoped that through increasing international cooperation on designing technological capability monitoring models and removing data limitation, especially in case of developing and less developed countries, the ground is prepared for more accurate evaluations of more countries in the field of technological capability.

References

- Arcelus, F., Sharma, B., Srinivasan, G., 2005. Assessing the information content of the technology achievement index in the presence of the human development index. Economics Bulletin, 15(4), PP 1−5.
- Archibugi, D., Coco, A., 2004. A New Indicator of Technological Capabilities for Developed and Developing Countries. World Development, 32(4), pp. 629-654.
- Archibugi, D., Denni, M., Filippetti, A., 2009. The technological capabilities of nations: The state of the art of synthetic indicators. Technological Forecasting & Social Change 76, PP 917–931.
- Arundel, A., Garrelfs, R., 1997. Innovation measurement and policies, European Commission, Brussels, EIMS publication no. 50.
- Chinaprayoon, C., 2007. Science, Technology And Innovation Composite Indicators For Developing Countries. Master Of Science In Public Policy In The School Of Public Policy. Georgia Institute Of Technology.
- Coe, D., Helpman, E., 1995. International R&D spillovers. European Economic Review 39, 859–887.
- Desai, M., Fukuda-Parr, S., Johansson, C., Sagasti, F., 2002. Measuring the technology achievement of nations and the capacity to
- participate in the network age. Journal of Human Development 3 (1), 95–122.
- De Vaus, D., 2002. Surveys in social research, Routledge, Australia.

- Furman, J., Porter, M., Stern, S., 2002. The Determinants of National Innovative Capacity. RESEARCH POLICY 31, pp 899 – 933.
- Grossman, G.M., Helpman, E., 1991. Innovation and Growth in the Global Economy. The MIT Press, Cambridge, MA.
- Kaiser, H.F., 1958. The Varimax Criterion For Analytic Rotation In Factor Analysis. Psychometrika 23, pp 187-200.
- Kim, L., 1997. Imitation to Innovation: The Dynamics of Korea's Technological Learning. Harvard Business School Press, Harvard.
- Kline, p., 2000. An Easy Guide to Factor analysis. Routledge, canada.
- Kline, P., 1994. An easy guide to factor analysis. Roudedge, London.
- Lall, S., 1992. Technological capabilities and industrialization. World Development 20, 165–186.
- Moon, H., Lee, J., 2005. A fuzzy set theory approach to national composite S&T indices. Scientometrics 64 (1),PP 67–83.
- Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., 2005. Tools for Composite Indicator building. European commission,Itlay, http://farmweb.jrc.cec.eu.int/ci/bibliography.htm.
- Norusis. M.J., 1986. The SPSS Guide to Data Analysis. Rush-Presbyterian-St Luke Medical Centre U.S.A.
- Oecd, 2008. Handbook on Constructing composite Indicators: Methodology and user Guide, www.oecd.org/publishing/corrigenda.
- Porter, M., Stern, S., 2000. Measuring the 'Ideas' Production Function: Evidence from International Patent Output. NBER Working Paper No. 7891. Massachusetts: National Bureau of Economic Research.
- Romijn, H., 1999. Acquisition of Technological Capabilities in Small Firms in Developing Countries. Macmillan Press, Basingstoke.
- Ulku, H., 2004. R&D, Innovation, and Economic Growth: an Empirical Analysis. IMF Working Paper. International Monetary Fund.
- United Nations Conference on Trade and Development (UNCTAD), 2008. World Investment Report 2008: Transnational Corporations and the Infrastructure Challenge. New York and Geneva.
- United Nations Development Program(UNDP), 2007. Human Development Report 2007-2008. Fighting climate change: human solidarity in a divided world. Palgrave Macmillan, Houndmills, http://www.undp.org.
- United Nations Development Program(UNDP), 2001. Human Development Report 2001. Making New Technologies Work for Human Development. Oxford University Press, New York,http://www.undp.org.
- United Nations Industrial Development Organization(UNIDO), 2009. Industrial Development Report 2009. Breaking In and Moving Up: New Industrial Challenges for the Bottom Billion and the Middle-Income Countries, http://www.unido.org.
- United Nations Industrial Development Organization(UNIDO). 2004. Industrial Development Report 2004. Industrialization, Environment and the Millennium Development Goals in Sub-Saharan Africa,The new frontier in the fight against poverty, http://www.unido.org.
- United Nations Industrial Development Organization(UNIDO), 2002. Industrial Development Report 2002–2003. Competing through Innovation and Learning. Vienna, http://www.unido.org.
- U.S. PATENT AND TRADEMARK OFFICE(USPTO), 2008. Extended Year Set - Historic Patents By Country, State, and Year Utility Patents. Washington, DC, Retrieved from http://www.uspto.gov on September 2009.
- Wagner, C., Horlings, E., Dutta, A., 2004. Can science and technology capacity be Measured?. University of Amsterdam, Netherlands.
- World Bank, 2009. Measuring Knowledge in the World Economies. Washington, DC, www.worldbank.org.
- World Bank-b, 2009. World Development Indicators.Washington, DC, http://www.worldbank.org.
- World Bank, 2008. Measuring Knowledge in the World Economies. Washington, DC, www.worldbank.org.
- World Economic Froum(WEF)., 2008. The Global Competitiveness Report 2008-2009. Geneva, Printed and bound in Switzerland by SRO-Kundig.
- World Economic Forum (WEF), 2001. The Global Competitiveness Report. Oxford University Press, New York.