Scientometrics (2011) 87:41–62
DOI 10.1007/s11192-010-0285-6

Technology achievement index 2009: ranking and comparative study of nations

Anthony Nasir · Tariq Mahmood Ali · Sheikh Shahdin · Tariq Ur Rahman

Received: 2 July 2010 / Published online: 4 September 2010

Abstract Ranking of 91 countries based on the Technology Achievement Index 2009 (TAI-09) (2009 refers to the year in which most of data collection was carried out.) is reported. Originally proposed in 2002, the TAI is a composite indicator which aggregates national technological capabilities and performance in terms of creation/diffusion of new technologies, diffusion of old technologies and development of human skills. In addition to the overall ranking of 91 countries, rankings in each sub-dimension of the Index are also reported. Comparative analysis of TAI ranking of 56 countries, common to the present and previous study of 2002 under similar conditions, is quite instructive and indicates shifts in technological scenario of these countries even over a relatively short period of 5–6 years. A simple concept based on Standard Deviation approach, as an indication of the technological spread or otherwise, is proposed for the first time. Application of this concept to 56 common countries is reported.

Keywords Technology achievement index · Technology development · Technology capability · Technology creation · Technology diffusion · Technology capability spread · Human skills

Introduction

The technology achievement of a county refers to the level of its technological readiness to participate in the global knowledge based economy. This can be described through a combination of appropriate indicators. Some of these indicators (*read* input indicators) may describe existing level of a country's technological ability to perform while others (*read* output indicators) may give strong evidence that the ability is dynamic and productive. An appropriate combination of the two gives fairly realistic idea about the technology achievement of a country. The Technology Achievement Index (TAI), originally

A. Nasir (✉) · T. M. Ali · S. Shahdin · T. U. Rahman
Pakistan Council for Science and Technology (PCST), Shahrah-e-Jamhuriat, Sector G-5/2, Islamabad, Pakistan
e-mail: anthonynasir2009@gmail.com

proposed in 2002 (Desai et al. 2002) and hereafter referred to as TAI-02, is one such composite index which aggregates national technological capabilities and performance in terms of (i) creation/diffusion of new technologies, (ii) diffusion of old technologies and (iii) development of human skills. It is a simple and relatively useful index for assessing the national technological capability of a country. The sub-indicators used in the TAI study are considered to practically cover all related aspects of technology achievement. As such it is a very useful index for countries to assess their relative technology based readiness in comparison with their competitors for participation in the global knowledge based economy.

The TAI focuses on assessing the technological performance of a country based on its capability in creating and using technology but NOT on the overall size of its technological development. It is for this reason that, for example, Finland a smaller country finds itself higher in TAI rankings than USA, UK and Germany.

The Index has four dimensions and each dimension is specified by two sub-indicators. The four dimensions and the corresponding sub-indicators are summarized below:

Dimensions	Sub-indicators
#1 Creation of technology	i. *Patents granted to residents (/million people)*: stock of embedded knowledge. An indirect indicator of knowledge that has been developed and could be tapped for future use. It also reflects the current level of inventive activity
	ii. *Receipts of royalties and license fee (US$/person)*: the indicator reflects the stock of successful past innovations that are still useful and hence have market value
#2 Diffusion of recent innovations	i. *Internet users (/1000 people)*: Diffusion of internet is indispensable for participation in the global economic activities. One of the most dynamic and powerful tools to access the global information at relatively low cost
	ii. *High-technology exports (%age of manufactured exports)*: the indicator is the best yardstick for measuring the annual average growth rates (AAGR) in high technology area of a country
#3 Diffusion of old technologies	i. *Electric power consumption (kWh/capita)*: the indicator gives a reasonably accurate idea about the diffusion of electricity within a society. The indicator is important because of its use in new technologies and also for a multitude of other human activities
	ii. *Telephone mainlines + cellular subscribers (/1000 people)*: this indicator shows the participation of the people in the communication revolution. Countries must adopt this old innovation to participate successfully in the present IT network era
#4 Human skills development	i. *Gross enrolment ratio at all levels, except pre-primary*: although the mean years of schooling was used as a proxy for cognitive skill, however, due to the non availability of relevant data in 2009, the present work uses 'Gross Enrollment Ratio' as a close proxy which can be used to measure overall level of education in population to develop cognitive skills
	ii. *Gross enrolment ratio in science, engineering, manufacturing and construction (tertiary)*: this indicator assesses the skills of a nation in science, mathematics, engineering and construction at the tertiary level

The main purpose of undertaking the current study is to see what changes, if any, have taken place in the TAI rankings of various countries since the seminal study by Desai et al. (2002), and whether these changes in the indices correspond more or less to the ground reality.

In contrast with the TAI-02 study that was limited to the overall rankings of 72 nations only, the present study analyses the technological capacities and capabilities of 91 nations. In addition to the overall ranking of these nations, it also gives their rankings in each individual dimension.

The study also compares the shifting sands of technological capacities and capabilities of 56 countries common to the TAI-09 and TAI-02 studies. For the comparison to be transparent and valid, rationalization of some of the sub-indicators used in TAI-02 was carried out as some of the data available in 2002 was no longer available in 2009 in the desired format.

A simple concept based on the variations in the Standard Deviation values of TA indices of a group of nations over a specific period as an indication of the spread or otherwise of technological capabilities of the countries over that period, is proposed for the first time. Application of this concept to 56 common countries is reported. Preliminary results appear to confirm the validity of the approach.

Data sources and data processing

One of the problems faced in the present work, common to all statistical studies, was related to reliable data collection. To avoid the difficult and time consuming process of collecting data for all eight sub-indicators directly for every country, statistical publications and databases of major international organizations have been relied upon. To remove any element of doubt, the data collected have been checked and rechecked and wherever possible, also counter-checked against alternate sources. The sub-indicators and their data sources are as follows:

Patents

The patent indicator used in the study is the number of patents granted to per million residents. Data corresponding to the period 2000–2005 has been taken from the Human Development Report, UNDP(United Nation Development Programme (Undp) 2008) and World Bank Online Database of Knowledge Assessment Methodology (World Bank 2009a).

Royalties and license fees

Data for royalties and license fees (US$/person), for the period 2004–2006, has been taken from the Human Development Report, UNDP(United Nation Development Programme (Undp) 2008) and World Bank Online Database of Knowledge Assessment Methodology (World Bank 2009b).

Internet

The data on actual users, (/1000 people), is preferred over that of ‘hosts’ as it gives a more precise idea about the diffusion of internet among the population. For this World Bank Database (2005) has been used.

High-technology exports

In TAI-02 (Desai et al. 2002), data of *high* and *medium* technology exports as percentage of manufactured export, was used. However, in spite of extensive internet search data for *medium* technology exports could not be traced. Private communications with other researchers (Wagner 2009; UIS and UNESCO 2009; Shahzad Sharjeel et al. 2009) were inconclusive as well. Therefore, the present study has been limited to the use of *high* technology exports only. Most of this data (as % age of manufactured exports, 2005–2006) is taken from the World Bank Database.

Telephones (mainline and cellular)

Data regarding telephone mainlines and cellular subscribers (/1000 people) for 2005–2006 has been taken from Human Development Report, 2007–2008 (United Nation Development Programme (Undp) 2008).

Electricity

The data of electricity power consumption (kWh/capita) for 2005 has been obtained form the World Bank Database.

Gross enrollment ratio (GER)

The indicator used in 2002 (Desai et al. 2002) to determine basic level of human skill is '*mean years of schooling*'. No fresh data for this sub-indicator is available any more in databases that contained this information previously. Once again, private communications with relevant research groups (Wagner 2009; UIS and UNESCO 2009; Sharjeel et al. 2009) did not help. Consequently, a modified indicator '*Gross Enrollment Ratio (GER)*' has been used in the present study. The idea being that higher gross enrollment (primary, secondary, tertiary) ratio of a country over a period of time would ultimately result in higher mean years of schooling. The data regarding Gross Enrolment Ratio, all levels combined (except pre-primary, 2005–2007), is retrieved from the Database of UNESCO Institute of Statistics (UIS).

Gross enrolment ratio in science, engineering, manufacturing and construction

This sub-indicator assesses human skills necessary to adapt to new technologies. For this, enrolment in tertiary education in science, mathematics and engineering as percentage of the population at tertiary level has been used. The data for gross enrolment ratio in science, engineering, manufacturing and construction at tertiary level, 2005–2007, was obtained form the Database of UNESCO Institutes of Statistics by adding together the separately given enrollments of a country in individual disciplines at tertiary level. The relevant GER of a country was calculated by following the UIS approach:[1]

$$\text{Gross enrollment ratio in science} = \frac{\text{Gross enrollment in science}}{\text{Population at tertiary level}} \times 100$$

Technology Achievement Index 2009 (TAI-09) has been calculated using goalposts Table 1 and TAI data given in Table 2, following the methodology outlined in TAI-02 (Desai et al. 2002).

[1] Includes engineering, manufacturing and construction.

Table 1 Goalposts for calculating the TAI-09 for 91 countries

S. no.	Name of indicator	Observed maximum value	Observed minimum value
1	Patents granted to residents per million people (2000–2005)	1113.000	0.000
2	Receipts of royalty and license fees in US$ per 1,000 people (2005–2006)	627.900	0.000
3	Internet users per 1000 people (2005)	796.576	2.414
4	High-technology exports (% of manufactured exports) (2005–2006)	70.726	0.000
5	Telephone (mainlines and cellular) per 1000 people (2005)	1397.000[a]	1.000
6	Electricity consumption, KWH per capita (2005)	9287.000[a]	10.000
7	Gross enrolment ratio, all levels combined (except pre-primary)(2003–2007)	113.440	39.770
8	Gross enrolment ratio in science, engineering, manufacturing and construction. Tertiary (2003–2007)	35.109	0.021

[a] Value caped at OECD average

Results and discussion

TAI values and country rankings

Table 2 lists the TAI-09 ranking of 91 countries. The values show great disparities not only among the countries as a whole but also within specific categories like the developed and developing countries. The highest TAI value is 0.765 for S. Korea whereas the lowest value is 0.111 for Cambodia. Following TAI-02 (Desai et al. 2002), the 91 countries based on their TAI values, have been classified as *Leaders* (TAI $\geq$ 0.5), *Potential Leaders* (0.35 $\leq$ TAI $\leq$ 0.49), *Dynamic Adopters* (0.20 $\leq$ TAI $\leq$ 0.34) and *Marginalized Countries* (TAI < 0.20).

Leaders

Eighteen countries fall in this category. These countries have attained excellent level of development of human skills, have successfully diffused old technologies within their societies, are exploiting recent technologies very well and can be termed as being at the cutting edge of technological innovation and consequently as leaders in science and technology, trade, industry and business.

Potential leaders

This group comprises of 33 countries including some developed and fast developing countries. Estonia is at the top while Romania is at the bottom of the list. UAE, although has zero value of technology creation index, stands in TAI ranking above Bulgaria, Argentina, Mexico and Romania who have definite values for technology creation Index. UAE, Bahrain and Brunei Darussalam (oil rich countries) are spending heavily on education and have high electricity consumption per capita. They are in this group mainly due to these two factors.

Also TAI values of these countries indicate that these countries have achieved high levels of human skill development and have been able to diffuse old technologies very

Table 2 The technology achievement index-2009 (TAI-09) with corresponding sub-indices and their rankings

Country name	Technology achievement index 2009	Overall ranking TAI -09	Technology creation (TC)				Diffusion of recent innovations (DRI)			
			Patents granted to residents (per million people) (2000–2005)	Receipts of royalties and licence fees (US$ per person) (2004–2006)	TC index	TC ranking	Internet users (per 1000 people) (2005)	High-technology exports (% of manufactured exports) (2005–2006)	DRI index	DRI ranking
1	2	3	4	5	6	7	8	9	10	11
Leader s (TAI > 0.5)										
Korea, Rep.	0.765	1	1,113	38.2	0.530	1	683.520	32.329	0.657	4
Finland	0.677	2	214	230.0	0.279	5	533.730	25.215	0.513	14
Sweden	0.661	3	166	367.7	0.367	4	763.516	16.675	0.597	6
Singapore	0.642	4	96	125.8	0.143	11	586.057	56.582	0.767	1
Japan	0.630	5	857	138.0	0.495	3	667.512	22.474	0.578	8
Netherlands	0.612	6	110	236.8	0.238	7	796.576	30.116	0.713	2
Luxembourg	0.609	7	31	627.9	0.514	2	689.716	11.806	0.516	13
United States	0.607	8	244	191.5	0.262	6	667.101	29.922	0.630	5
United Kingdom	0.569	9	62	220.8	0.204	8	567.857	28.016	0.554	10
Canada	0.548	10	35	107.6	0.101	15	680.862	14.428	0.529	12
Norway	0.544	11	103	78.4	0.109	13	584.431	17.310	0.489	16
New Zealand	0.544	12	10	24.8	0.024	27	666.199	10.370	0.491	15
Ireland	0.539	13	80	142.2	0.149	9	336.611	34.526	0.454	18
Australia	0.536	14	31	25.0	0.034	24	465.690	12.742	0.382	26
Germany	0.531	15	158	82.6	0.137	12	432.888	16.954	0.391	25
France	0.528	16	155	97.1	0.147	10	429.649	20.023	0.411	21
Iceland	0.527	17	0	0.0	0.000	76	616.617	27.077	0.578	7
Estonia	0.501	18	56	4.0	0.028	25	512.592	17.565	0.445	19

Table 2 continued

Country name	Technology achievement index 2009	Overall ranking TAI -09	Technology creation (TC)				Diffusion of recent innovations (DRI)			
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1	2	3	4	5	6	7	8	9	10	11
Potential Leaders (TAI = 0.35–0.499)										
Slovenia	0.499	19	113	8.2	0.057	19	544.864	4.612	0.374	27
Greece	0.495	20	29	5.4	0.017	35	180.205	10.188	0.184	49
Belgium	0.491	21	51	106.5	0.108	14	458.074	8.661	0.348	30
Spain	0.491	22	53	12.9	0.034	23	397.091	7.052	0.298	32
Malaysia	0.490	23	7	1.1	0.004	47	488.727	54.706	0.693	3
Austria	0.489	24	92	21.3	0.058	18	485.832	13.528	0.400	23
Italy	0.482	25	71	19.3	0.047	20	477.758	7.767	0.354	29
Israel	0.473	26	48	91.2	0.094	16	243.497	13.933	0.250	40
Hungary	0.467	27	13	82.7	0.072	17	297.411	25.693	0.367	28
Malta	0.466	28	0	7.5	0.006	43	315.358	52.119	0.565	9
Barbados	0.461	29	–	5.8	0.005	45	548.071	18.381	0.473	17
Hong Kong, China	0.451	30	5	31.2	0.027	26	517.554	15.589	0.435	20
Portugal	0.439	31	14	5.7	0.011	40	270.736	8.986	0.232	44
Czech Republic	0.436	32	34	6.2	0.020	30	272.618	12.751	0.260	39
Latvia	0.434	33	36	4.3	0.020	32	447.729	5.291	0.318	31
Belarus	0.433	34	76	0.3	0.034	22	347.234	2.595	0.235	42
Cyprus	0.430	35	7	18.1	0.018	33	430.193	18.218	0.398	24
Poland	0.416	36	28	1.6	0.014	37	328.932	3.850	0.233	43
Philippines	0.411	37	–	0.10	0.000	71	54.570	70.726	0.533	11
Slovak Republic	0.410	38	9	9.2	0.011	39	353.657	7.283	0.273	36

Table 2 continued

Country name	Technology achievement index 2009	Overall ranking TAI -09	Technology creation (TC)				Diffusion of recent innovations (DRI)			
			Patents granted to residents (per million people) (2000–2005)	Receipts of royalties and licence fees (US$ per person) (2004–2006)	TC index	TC ranking	Internet users (per 1000 people) (2005)	High-technology exports (% of manufactured exports) (2005–2006)	DRI index	DRI ranking
1	2	3	4	5	6	7	8	9	10	11
Croatia	0.403	39	4	16.1	0.015	36	331.372	11.514	0.289	34
Ukraine	0.402	40	52	0.5	0.024	28	169.833	3.656	0.131	57
Chile	0.398	41	1	3.3	0.003	49	276.827	6.489	0.219	45
United Arab Emirates	0.387	42	–	–	0.000	77	322.027	10.200	0.273	35
Bulgaria	0.386	43	10	0.7	0.005	44	205.647	4.680	0.161	52
Bahrain	0.383	44	0	–	0.000	78	213.856	0.039	0.133	56
Costa Rica	0.381	45		0.12	0.000	70	213.185	37.979	0.401	22
Argentina	0.379	46	4	1.4	0.003	50	177.135	6.570	0.156	53
Brunei Darussalam	0.375	47	–	–	0.000	79	361.000	6.359	0.271	37
Mexico	0.364	48	1	0.7	0.001	55	174.276	19.552	0.246	41
Romania	0.363	49	24	2.2	0.013	38	220.620	3.435	0.162	51
Georgia	0.360	50	42	2.1	0.021	29	60.674	25.177	0.215	46
Uruguay	0.356	51	1	–	0.000	59	202.074	2.199	0.141	54
Dynamic Adopters (TAI = 0.200−0.34)										
Lebanon	0.341	52	–	0.0	0.000	80	174.531	2.400	0.125	59
Brazil	0.335	53	1	0.5	0.001	56	171.974	12.837	0.198	48
China	0.334	54	16	0.1	0.007	42	85.090	30.603	0.268	38
South Africa	0.326	55	–	0.9	0.001	58	76.771	6.578	0.093	64
Iran, Islamic Rep.	0.325	56	8	0.0	0.004	48	178.036	2.407	0.128	58
Guyana	0.321	57	0.00	47.9	0.038	21	216.371	0.188	0.136	55

Table 2 continued

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1	2	3	4	5	6	7	8	9	10	11
Jordan	0.319	58	–	–	0.000	81	133.019	1.361	0.092	65
Panama	0.319	59	–	0.0	0.000	82	114.844	0.851	0.077	70
Tajikistan	0.317	60	2	0.2	0.001	54	2.980	41.080	0.291	33
Colombia	0.314	61	–	0.2	0.000	68	105.428	4.916	0.100	63
Lithuania	0.314	62	–	0.2	0.000	67	258.591	6.121	0.205	47
Tunisia	0.313	63	–	1.4	0.001	53	95.101	4.383	0.089	66
Turkey	0.312	64	1	0.0	0.000	60	155.475	1.500	0.107	62
Mongolia	0.307	65	44	–	0.020	31	105.051	0.094	0.065	76
Trinidad and Tobago	0.303	66	–	–	0.000	83	123.138	1.345	0.086	67
Peru	0.299	67	–	0.1	0.000	72	168.657	2.608	0.123	60
Oman	0.297	68	–	–	0.000	84	113.680	0.275	0.072	71
Kyrgyz Republic	0.296	69	17	0.4	0.008	41	106.931	1.829	0.079	69
El Salvador	0.278	70	–	0.4	0.000	64	95.526	3.643	0.084	68
Algeria	0.274	71	1	–	0.000	61	58.440	1.484	0.046	79
Albania	0.268	72	0.00	0.2	0.000	69	59.612	4.967	0.071	72
Namibia	0.266	73	0.00	1.86	0.001	51	39.889	11.902	0.108	61
Morocco	0.263	74	1	0.4	0.001	57	152.607	9.627	0.163	50
Armenia	0.263	75	39	–	0.018	34	53.353	0.602	0.036	80
Cuba	0.262	76	3	–	0.001	52	16.874	–	0.009	89
Honduras	0.261	77	1	0.0	0.000	62	37.779	6.239	0.066	75

Table 2 continued

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1	2	3	4	5	6	7	8	9	10	11
Botswana	0.260	78	0.00	0.3	0.000	65	32.681	0.200	0.020	85
Guatemala	0.248	79	–	–	0.000	85	78.681	3.226	0.071	73
Uzbekistan	0.244	80	10	–	0.004	46	33.630	–	0.020	86
India	0.215	81	1	–	0.000	63	54.815	4.829	0.067	74
Marginalized (TAI < 0.200)										
Mozambique	0.179	82	–	0.1	0.000	73	8.669	7.507	0.057	77
Cameroon	0.173	83	–	0.02	0.000	75	14.049	2.148	0.023	84
Bhutan	0.172	84	–	–	0.000	86	39.246	–	0.023	83
Ghana	0.169	85	0.00	0.0	0.000	87	17.808	0.167	0.011	87
Pakistan	0.168	86	0	0.1	0.000	74	67.406	1.387	0.051	78
Nigeria	0.167	87	–	–	0.000	88	35.372	1.700	0.033	81
Uganda	0.150	88	–	0.3	0.000	66	17.273	2.344	0.026	82
Bangladesh	0.147	89	0.00	0.00	0.000	89	2.414	–	0.000	91
Tanzania	0.127	90	–	0.0	0.000	90	9.988	0.826	0.011	88
Cambodia	0.111	91	–	–	0.000	91	3.153	0.200	0.002	90

Table 2 continued

Country name	Diffusion of old innovations (DOI)				Development of human skills (DHS)			
	Telephone mainlines + cellular subscribers a (per 1,000 people) (2005–2006)	Electric power consumption (kWh per capita) (2005)	DOI index	DOI ranking	Gross enrolment ratio. All levels combined (except pre-primary). Total (2005–2007)	Gross enrolment ratio in science, engineering, manufacturing and construction. Tertiary (2005–2007)	DHS index	DHS ranking
1	12	13	14	15	16	17	18	19
Leader s (TAI > 0.5)								
Korea, Rep.	1286	7778.624	0.981	11	97.23	35.109	0.890	2
Finland	1401	16119.784	1.000	1	101.38	34.916	0.915	1
Sweden	1652	15440.4236	1.000	1	95.593	21.156	0.680	5
Singapore	1435	8507.197	0.994	5	87.00	24.200	0.665	6
Japan	1202	8232.577	0.981	12	85.81	10.782	0.466	34
Netherlands	1436	6987.748	0.979	14	97.24	9.116	0.520	25
Luxembourg	2111	15970.762	1.000	1	94.40	2.392	0.405	41
United States	1286	13647.577	0.994	3	92.75	12.818	0.542	23
United Kingdom	1616	6253.496	0.971	18	92.75	13.231	0.548	22
Canada	1080	17284.693	0.982	10	99.27	12.200	0.577	16
Norway	1488	25137.456	1.000	1	98.44	12.791	0.580	14
New Zealand	1283	9656.015	0.994	4	107.64	14.347	0.665	7
Ireland	1501	6233.560	0.971	19	97.70	13.119	0.580	15
Australia	1470	11480.533	1.000	1	113.44	16.079	0.729	4
Germany	1627	7110.589	0.980	13	99.53	14.851	0.617	10
France	1375	7938.331	0.987	9	95.52	13.333	0.568	18
Iceland	1677	27986.521	1.000	1	95.18	10.860	0.531	24
Estonia	1402	5567.194	0.963	23	92.21	14.887	0.568	19

Table 2 continued

Country name	Diffusion of old innovations (DOI)				Development of human skills (DHS)			
	Telephone mainlines + cellular subscribers a (per 1,000 people) (2005–2006)	Electric power consumption (kWh per capita) (2005)	DOI index	DOI ranking	Gross enrolment ratio. All levels combined (except pre-primary). Total (2005–2007)	Gross enrolment ratio in science, engineering, manufacturing and construction. Tertiary (2005–2007)	DHS index	DHS ranking
1	12	13	14	15	16	17	18	19
Potential leaders (TAI = 0.35–0.499)								
Slovenia	1287	6917.771	0.973	16	91.45	16.841	0.590	11
Greece	1472	5241.535	0.958	25	99.70	29.083	0.821	3
Belgium	1364	8509.970	0.992	7	94.13	10.329	0.516	26
Spain	1374	6147.128	0.969	20	95.77	19.770	0.661	8
Malaysia	943	3261.609	0.896	37	71.45	10.797	0.369	54
Austria	1441	7888.696	0.988	8	89.97	11.789	0.508	27
Italy	1659	5668.738	0.964	22	90.54	15.422	0.564	21
Israel	1544	6759.056	0.977	15	90.03	16.211	0.572	17
Hungary	1257	3771.370	0.927	30	89.36	11.638	0.502	30
Malta	1304	4916.976	0.949	28	81.31	4.344	0.344	59
Barbados	1265	3304.000	0.918	33	92.894	6.100	0.447	37
Hong Kong, China	1798	5878.442	0.967	21	74.42	9.842	0.375	53
Portugal	1486	4662.518	0.950	27	89.04	16.211	0.565	20
Czech Republic	1465	6343.211	0.972	17	82.70	13.933	0.490	32
Latvia	1132	2702.456	0.895	38	91.05	11.000	0.504	29
Belarus	755	3208.502	0.880	40	88.86	17.503	0.582	13
Cyprus	1503	5559.514	0.962	24	77.56	5.930	0.341	60
Poland	1073	3437.324	0.909	36	87.62	12.804	0.507	28

Table 2 continued

Country name	Diffusion of old innovations (DOI)				Development of human skills (DHS)			
	Telephone mainlines + cellular subscribers a (per 1,000 people) (2005–2006)	Electric power consumption (kWh per capita) (2005)	DOI index	DOI ranking	Gross enrolment ratio. All levels combined (except pre-primary). Total (2005–2007)	Gross enrolment ratio in science, engineering, manufacturing and construction. Tertiary (2005–2007)	DHS index	DHS ranking
1	12	13	14	15	16	17	18	19
Philippines	460	588.072	0.721	68	80.59	7.875	0.389	48
Slovak Republic	1065	4919.807	0.935	29	79.22	10.751	0.421	38
Croatia	1097	3474.856	0.911	35	76.70	10.279	0.397	46
Ukraine	622	3246.036	0.867	42	87.70	18.176	0.584	12
Chile	860	3074.298	0.886	39	82.91	13.475	0.485	33
United Arab Emirates	1273	13708.092	0.994	6	71.433	4.795	0.283	68
Bulgaria	1128	4121.189	0.926	31	81.95	11.638	0.452	35
Bahrain	1300	11400.575	0.995	2	87.20	5.767	0.404	42
Costa Rica	575	1718.883	0.815	50	72.98	5.915	0.309	62
Argentina	797	2417.881	0.863	43	88.61	11.528	0.495	31
Brunei Darussalam	847	7498.041	0.950	26	77.72	1.577	0.280	69
Mexico	649	1898.609	0.831	48	79.03	7.915	0.379	52
Romania	820	2341.924	0.862	44	77.01	11.307	0.414	39
Georgia	477	1671.879	0.800	54	76.48	10.788	0.403	43
Uruguay	623	2007.125	0.832	46	90.44	7.465	0.450	36
Dynamic adopters (TAI = 0.200–0.34)								
Lebanon	554	2241.980	0.832	47	76.78	11.011	0.408	40
Brazil	230	2008.203	0.763	60	87.21	4.027	0.379	51
China	571	1780.544	0.817	49	68.697	3.200	0.242	72
South Africa	825	4847.179	0.916	34	76.81	3.066	0.295	63

Table 2 continued

Country name	Diffusion of old innovations (DOI)				Development of human skills (DHS)			
	Telephone mainlines + cellular subscribers a (per 1,000 people) (2005–2006)	Electric power consumption (kWh per capita) (2005)	DOI index	DOI ranking	Gross enrolment ratio. All levels combined (except pre-primary). Total (2005–2007)	Gross enrolment ratio in science, engineering, manufacturing and construction. Tertiary (2005–2007)	DHS index	DHS ranking
1	12	13	14	15	16	17	18	19
Iran, Islamic Rep.	384	2116.547	0.803	52	73.20	9.756	0.366	55
Guyana	522	1090.000	0.775	58	86.05	1.549	0.336	61
Jordan	423	1675.506	0.792	56	79.29	8.815	0.394	47
Panama	554	1499.612	0.803	51	79.54	8.985	0.398	45
Tajikistan	80	2266.797	0.699	71	70.78	4.564	0.275	70
Colombia	647	890.072	0.775	59	76.07	9.549	0.382	49
Lithuania	1	3104.004	0.420	83	92.88	19.005	0.631	9
Tunisia	691	1193.938	0.801	53	76.07	7.900	0.359	57
Turkey	868	1897.592	0.851	45	68.61	6.634	0.290	67
Mongolia	279	1260.000	0.743	65	77.87	9.927	0.400	44
Trinidad and Tobago	861	5038.067	0.922	32	61.06	4.102	0.203	78
Peru	280	847.612	0.714	69	87.51	2.528	0.360	56
Oman	622	3756.618	0.878	41	67.25	3.651	0.238	74
Kyrgyz Republic	190	1842.131	0.744	64	77.50	6.916	0.354	58
El Salvador	491	665.531	0.735	66	72.90	4.708	0.292	66
Algeria	494	898.638	0.757	63	74.03	4.325	0.294	64
Albania	493	1167.189	0.776	57	67.80	2.331	0.223	75
Namibia	308	1427.951	0.759	62	67.28	0.761	0.197	79
Morocco	455	643.539	0.727	67	58.76	2.414	0.163	81

Table 2 continued

Country name	Diffusion of old innovations (DOI)				Development of human skills (DHS)			
	Telephone mainlines + cellular subscribers a (per 1,000 people) (2005–2006)	Electric power consumption (kWh per capita) (2005)	DOI index	DOI ranking	Gross enrolment ratio. All levels combined (except pre-primary). Total (2005–2007)	Gross enrolment ratio in science, engineering, manufacturing and construction. Tertiary (2005–2007)	DHS index	DHS ranking
1	12	13	14	15	16	17	18	19
Armenia	298	1503.151	0.760	61	70.85	2.024	0.240	73
Cuba	87	1151.875	0.656	74	87.49	4.095	0.382	50
Honduras	247	625.685	0.683	73	74.77	3.953	0.294	65
Botswana	541	1405.821	0.796	55	70.62	0.885	0.222	76
Guatemala	457	522.048	0.712	70	66.98	1.818	0.210	77
Uzbekistan	95	1659.395	0.688	72	74.18	2.080	0.263	71
India	127	480.486	0.618	75	60.65	2.235	0.173	80
Marginalized (TAI < 0.200)								
Mozambique	66	450.161	0.568	78	52.68	0.346	0.092	88
Cameroon	144	196.121	0.561	79	52.34	1.647	0.108	85
Bhutan	110	229.000	0.554	80	54.14	0.977	0.111	84
Ghana	144	265.764	0.583	77	50.30	0.825	0.083	90
Pakistan	116	456.224	0.608	76	39.77	1.071	0.015	91
Nigeria	150	126.595	0.532	81	55.00	0.021	0.103	86
Uganda	56	63.000	0.413	84	62.53	0.364	0.159	82
Bangladesh	71	135.561	0.485	82	52.15	1.226	0.101	87
Tanzania	56	61.204	0.410	85	51.94	0.351	0.087	89
Cambodia	78	10.000	0.301	86	59.16	0.716	0.141	83

'–' Data on patents and royalties are missing for these countries. Lack of data for these countries generally indicates little formal innovation occurring. Therefore, a value '0' for the missing indicates has been used for these countries in the present study well. Technology creation capabilities of some countries such as Belgium, Spain, Austria, Italy, Israel and Hungary and Hong Kong are either higher or comparable with some of the Leaders. Some countries of this group have attained very good levels of capability for diffusion of recent innovations, again at par with the leaders. Even countries like Malaysia, Malta and Philippines are exporting high tech manufactured goods which are 54.7, 52.12 and 70.73% of their respective total manufactured exports.

Dynamic adopters

Thirty countries come under this category. Most of the countries in this group are developing countries including Brazil, China, South Africa, Iran, Turkey and India. These countries have devised effective methodologies for exploiting new technologies. Among them Brazil, China and India have developed important high-technology industries and technology hubs. Apart from India, their human skill development level is significant and improving further. However, the diffusion of old technologies (electricity, telephone, roads, railways, air and sea transportation etc.) in these countries is slow and incomplete particularly in rural areas. Due to limited access to power and communications facilities, there are gaps in the pace of development in rural and urban areas. India with second largest population needs to invest heavily in human skill development as well as diffusion of old technologies.

Marginalized countries

These countries lag behind in almost every dimension of technological achievement. Human skill development and diffusion of old technologies have a long way to go in these countries. Consequently, the situation regarding technology creation and diffusion of recent technologies is still poor. Pakistan with the 6th largest population in the world is behind all 90 countries in the dimension of human skill development, which is a major obstacle in Pakistan's knowledge based sustainable economic growth and its significant participation in the global knowledge based economy.

Comparison of 56 countries common to TAI-02 and TAI-09 studies

For a valid and meaningfull comparision of technological achivement of countries common to the TAI-02 and TAI-09 studies, a rationalization of their sub-indicators was crucial. As stated previously, following revised sub-indicators were used in the TAI-09 study as data for the corresponding sub-indicators used in 2002 was no longer available:

1. High-technology exports (as % age of manufactured exports) instead of high and medium technology exports as percentage of manufactured exports.
2. Gross Enrolment Ratio in science, engineering, manufacturing and construction instead of mean years of schooling.

This lead to the revision of the two corresponding goalposts (observed max. and min. values) while the other six goalposts remained the same (Desai et al. 2002).

S. no.	Sub-indicator	Observed maximum value	Observed minimum value
1	High-technology exports (% of manufactured exports) (2000)	72.577	0.026
2	Gross enrolment ratio, all levels combined, except pre-primary. (1999-2000)	115.82	31.00

Subsequently, the TAI-02 was revisited for all 72 countries with the revised goalposts in order to make it compatible with TAI-09. The resulting modified TAI-02, henceforth referred to as *TAI-02(M)* along with the original TAI-02, are listed in Table 3. Minor changes in the rankings of countries, inevitable as a result of data rationalization, can be observed. It is to be noted that all subsequent comparisons and discussions regarding the relative technological achievement status of nations in 2002 and 2009 refer to the modified data TAI-02(M) and NOT the original data of TAI-02 (Desai et al. 2002).

Once the unification of relevant sub-indicators for 2002 and 2009 was completed, 56 countries common to the TAI-09 and TAI-02(M) were selected. Minor adjustments to the goalposts were necessary as a result of the reduction in the number of countries from 91 to 56 for TAI-09 and from 72 to 56 for TAI-02(M). Following the procedure already adopted, the TAI rankings of 56 countries in 2009 and 2002 were calculated and are shown in Table 4. For the sake of completeness, the ranking of these nations in individual sub-dimensions are also indicated.

The comparision is quite instructive and offers some interesting perspectives:

- Generally speaking, within 56 countries 20 countries moved up while 23 countries moved down in TAI rankings whereas 13 countries including Sweden, Japan, Iceland, and Norway retained their ranking positions.
- Group of 16 industrialized countries including USA, UK, France, Germany and Japan which was at the top of the list in 2002 maintained its top position with minor shifts in the ranking of countries within in the group.
- Among the countries moving upwards, shifts in the ranking of Korea Republic, Singapore, Canada, Germany, Slovenia, Greece, Cyprus, Poland, Romania and China are quite noticeable. Korea moved up in TAI ranking from 9th to 1st position. It performed well in all sub-dimensions particularly in technology creation and diffusion of recent innovations.
- Singapore moved up from 8th to 4th position with main contributing factors being its better performance in technology creation and diffusion of recent innovations.
- Canada's ranking shifted from 13th to 9th position with the only contribution coming from improvement in diffusion of recent innovations.
- Germany moved from 16th to 13th position, the main reasons being improvement in diffusion of recent innovations and development of human skills.
- Malaysia performed better in technology creation, diffusion of recent innovations and human skill development, consequently moving up from 26th to 23rd position.
- China improved in technology creation and diffusion of old technologies, moving from 47th to 41st position.
- Iran's performance in technology creation and diffusion of recent innovations was significant; moving up from 46th to 43rd spot.

Table 3 TAI-02(M) with new Index values and rankings

Country	TAI-02(M)	Ranking TAI-02(M))	Overall ranking TAI-02[1]	Country	TAI-02(M)	Ranking (TAI-02(M))	Overall ranking TAI-02
Finland	0.722	1	1	Brazil	0.334	37	43
Sweden	0.656	2	3	Cyprus	0.328	38	33
United States	0.652	3	2	Uruguay	0.326	39	38
Netherlands	0.615	4	6	South Africa	0.319	40	39
Australia	0.606	5	10	Mexico	0.319	41	32
Korea, Rep	0.604	6	5	Romania	0.305	42	35
Japan	0.604	7	4	Panama	0.298	43	42
Singapore	0.597	8	8	Peru	0.282	44	48
Ireland	0.562	9	13	Colombia	0.280	45	47
United Kingdom	0.559	10	7	Jamaica	0.277	46	49
Norway	0.554	11	12	Trinidad Tobago	0.276	47	41
New Zealand	0.526	12	15	Iran	0.271	48	50
Belgium	0.521	13	14	Paraguay	0.263	49	52
Canada	0.521	14	9	China	0.261	50	45
France	0.496	15	17	Thailand	0.261	51	40
Germany	0.494	16	11	Ecuador	0.259	52	54
Austria	0.490	17	16	Dominican Republic	0.252	53	55
Israel	0.479	18	18	Tunisia	0.251	54	51
Spain	0.430	19	19	El Salvador	0.247	55	53
Greece	0.423	20	26	Algeria	0.241	56	58
Italy	0.418	21	20	Egypt, Arab Rep.	0.239	57	57
Slovenia	0.411	22	23	Syrian Arab Republic	0.227	58	56
Hong Kong, China (D)	0.407	23	24	Indonesia	0.220	59	60
Portugal	0.401	24	27	Nicaragua	0.203	60	64
Hungary	0.399	25	22	Honduras	0.201	61	61
Malaysia	0.384	26	30	Zimbabwe	0.192	62	59
Czech Republic	0.374	27	21	Sri Lanka	0.188	63	62
Argentina	0.366	28	34	India	0.171	64	63
Philippines	0.364	29	44	Pakistan	0.133	65	65
Costa Rica	0.362	30	36	Ghana	0.130	66	67
Chile	0.350	31	37	Kenya	0.119	67	68
Slovak Republic	0.348	32	25	Senegal	0.116	68	66
Bulgaria	0.344	33	28	Nepal	0.104	69	69
Poland	0.343	34	29	Mozambique	0.082	70	72
Croatia	0.342	35	31	Sudan	0.067	71	71
Bolivia	0.335	36	46	Tanzania	0.054	72	70

For comparison, the original TAI-02 rankings are also indicated

Table 4 Comparison of 56 countries common to TAI-09 and TAI-02(M) studies

S. no.	Country name	TAI ranking 2009	TAI ranking 2002(M)	Technology creation 2009	Technology creation 2002(M)	Diffusion of recent innovations 2009	Diffusion of recent innovations 2002(M)	Diffusion of old innovations 2009	Diffusion of old innovations 2002(M)	Development of human skills 2009	Development of human skills 2002(M)
1.	Korea, Rep.	1	9	1	7	4	19	9	15	2	3
2.	Sweden	2	2	3	2	6	7	1	1	5	5
3.	Finland	3	1	4	5	11	1	1	1	1	2
4.	Singapore	4	8	10	19	1	3	4	3	6	4
5.	Japan	5	5	2	1	7	15	10	1	28	25
6.	Netherlands	6	4	6	3	2	5	12	8	20	20
7.	United States	7	3	5	4	5	2	2	1	19	12
8.	United Kingdom	8	7	7	6	8	14	16	12	18	10
9.	Canada	9	13	14	13	10	12	8	2	13	9
10.	Ireland	10	10	8	8	14	8	17	14	12	15
11.	Norway	11	11	12	15	13	4	1	1	11	14
12.	New Zealand	12	14	23	17	12	10	3	9	7	7
13.	Germany	13	16	11	10	20	22	11	10	9	13
14.	France	14	15	9	11	16	18	7	6	15	16
15.	Australia	15	6	21	16	21	9	1	4	4	1
16.	Belgium	16	12	13	9	25	23	5	5	21	6
17.	Slovenia	17	22	18	18	22	33	14	17	10	22
18.	Greece	18	21	26	46	37	27	22	18	3	11
19.	Austria	19	17	17	14	18	16	6	7	22	17
20.	Spain	20	19	20	20	26	30	18	19	8	8
21.	Israel	21	18	15	12	31	17	13	11	14	23
22.	Italy	22	20	19	21	24	26	20	16	17	21
23.	Malaysia	23	26	34	47	3	11	31	30	40	48
24.	Hungary	24	25	16	23	23	21	25	24	24	29
25.	Hong Kong, China	25	23	22	35	15	20	19	13	39	35
26.	Portugal	26	24	31	28	34	31	23	20	16	18
27.	Czech Republic	27	27	24	24	30	29	15	21	26	32
28.	Cyprus	28	36	25	48	19	38	21	22	44	44
29.	Poland	29	34	28	27	33	41	30	28	23	28
30.	Slovak Republic	30	30	30	26	28	40	24	23	31	34
31.	Croatia	31	35	27	32	27	34	29	27	34	30
32.	Chile	32	31	36	25	35	45	32	31	27	24
33.	Bulgaria	33	33	33	29	39	47	26	25	29	27
34.	Philippines	34	32	49	45	9	6	46	45	35	37

Table 4 continued

S. no.	Country name	TAI ranking		Rankings in sub-dimensions							
				Technology creation		Diffusion of recent innovations		Diffusion of old innovations		Development of human skills	
		2009	2002(M)	2009	2002(M)	2009	2002(M)	2009	2002(M)	2009	2002(M)
35.	Argentina	35	28	37	30	40	32	33	33	25	19
36.	Costa Rica	36	29	48	39	17	13	38	36	45	46
37.	Romania	37	41	29	22	38	43	34	35	32	38
38.	Mexico	38	40	39	36	32	24	36	38	38	41
39.	Uruguay	39	38	42	38	41	37	35	32	30	33
40.	South Africa	40	39	41	31	45	35	28	26	46	40
41.	China	41	47	32	40	29	28	37	41	50	49
42.	Trinidad and Tobago	42	43	54	50	47	49	27	29	51	51
43.	Iran, Islamic Rep.	43	46	35	43	42	52	40	40	41	39
44.	Panama	44	42	53	49	49	54	39	37	33	31
45.	Brazil	45	37	40	33	36	25	43	34	37	36
46.	Tunisia	46	48	38	34	46	50	41	42	43	45
47.	Colombia	47	44	47	37	44	39	42	39	36	42
48.	Peru	48	45	50	41	43	48	47	44	42	26
49.	El Salvador	49	49	46	42	48	44	45	43	49	47
50.	Algeria	50	50	43	51	54	42	44	46	47	43
51.	Honduras	51	51	44	52	51	56	48	47	48	50
52.	India	52	52	45	44	50	46	49	48	52	52
53.	Ghana	53	54	55	54	55	51	51	50	55	53
54.	Pakistan	54	53	52	53	53	55	50	49	56	55
55.	Mozambique	55	55	51	55	52	36	52	52	53	54
56.	Tanzania	56	56	56	56	56	53	53	51	54	56

- Finland, United States, Australia, Belgium, Israel, Argentina, Costa Rica and Brazil moved downwards. United States showing descending trends in all four dimensions falls 4 ranks and is now placed at 7th position

Concept of standard deviation (SD) technique applied to TAI

Standard Deviation, in principle, represents the spread of data points around a mean value. Low SD indicates that the data points are closer to the mean value, while higher value signifies that the data points are relatively spread apart. The present study, for the first time, extends this concept to the SD of TAI values, where the points now simply are the S&T capability of nations. Any spread or otherwise of these points over a specific period should then represent the fluctuating S&T capability fortunes of nations over that specific period.

Table 5 SD calculation of technology achievement index (TAI) of 56 common countries

Year/data	TAI-09	TAI-02(M)
Sum	22.999	21.831
Mean	0.411	0.390
Variance	0.028	0.030
Standard Deviation	0.166	0.175
Percent change	−4.699	

Table 6 SD calculation of TAI of 25 OECD countries out of 56 common countries

Year/data	TAI-09	TAI-02(M)
Sum	13.453	13.123
Mean	0.538	0.525
Variance	0.011	0.016
Standard Deviation	0.103	0.128
Percent change	−19.704	

Table 7 SD calculation of TAI of 31 non-OECD countries out of 56 common countries

Year/data	TAI-09	TAI-02(M)
Sum	9.546	8.708
Mean	0.308	0.281
Variance	0.018	0.015
Standard deviation	0.134	0.124
Percent change	8.066	

Table 5 shows the SD values of 56 common countries. Shrinkage in the TAI values of 4.7% from 2002 to 2009 can be observed, indicating that even if slowly, nations have tried to bridge the S&T capability gap over this period.

The situation becomes interesting if we break up the 56 countries into OECD and non-OECD countries. Tables 6 and 7 show the results of SD analysis for 25 OECD and 31 Non-OECD countries.

While the shrinkage in SD of TAI values for OECD countries over 2002–2009 was almost 20%, in case of non-OECD countries on the contrary a spread in the SD values of around 8% over the same period was observed. This very simple analysis confirms the fact that while OECD countries were quick to grasp the role of S&T in national uplift, the attitude of non-OECD countries already lagging behind in S&T development left a lot to be desired.

In principle, the concept of standard deviation of TAI values as a tool for assessing the technological readiness of nations appears to be working reasonably. However, at this stage, a more detailed analysis of the same is suggested.

Future perspectives

Finally, the TAI appears to be a reasonable composite S&T indicator for assessing the technological readiness of a nation without saying anything about her overall S&T

capability. As such, it may be useful in some detailed study of regional technical capabilities for example SAARC nations for being of direct interest, oil producing countries due to their critical role in world economy and Central Asian republics as a future source of world's energy supplies. At this stage, it may also be worthwhile to re-visit the structure of not only TAI but other composite S&T indicators like Science and Technology Capacity Index-2002 (STCI-02)(Wagner et al. 2002), New Indicator of Technological Capabilities (ArCO)(Working Paper No. 11 A new indicator of technology capabilities for developed and developing countries (ArCO) 2004), High Technology Indicators (HTI) (Porter et al. 2005) in order to assess their suitability or otherwise to developing countries. This is necessary as these indicators have generally been developed in the overall context of technologically advanced nations. As a starting point, a rationalization of the weightings of some sub-indicators may be necessary.

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