Technological Achievements and Economic Development: The Significance of Technological Achievement Gap in Selected East and South Asian Countries†

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Abstract

Although technological progress is considered a key element for economic growth and development of a country, strong empirical evidence in this regard is not available yet. Therefore, to establish the empirical link between technology progress and economic development, it is advisable to carry out a time series analysis. In this regard, the Technology Achievement Index (TAI) of 100 top economies has been developed to examine the position of countries' technological progress for the 21 years spanning 1995 to 2015. Countries have been ranked on their TAI which is based on four pillars; technology creation, diffusion of older innovations, diffusion of recent innovations, and development of human skills. As well, this current study re-calculates the Humane Development Index (HDI) of 100 top economies for the 21 years from 1995 to 2015. Ranking of countries' HDI values reflects three dimensions: A long lifespan (life expectancy index), knowledge (Education Index) and a decent standard of living (Gross National Income Index, or GNI). The Standard Deviation (SD) technique has been used to investigate the technological gap between individual countries and groups of countries or regions. For a more meaningful assessment, technological gaps from the maximum achievement value (i.e., one of the countries under study) are presented as well. To investigate the impact of technological progress on economic development, this study introduces a model in which the HDI is used as the dependent variable and the TAI and Gross Capital Formation (GCF) are used as independent variables. The HDI, TAI and GCF are used in this model as proxy variables for economic development, technological progress and capital respectively. Econometric techniques have been used to show the impact of technological progress on economic development. The results show that long-term associations exist between technology progress and economic development; the impact of technology progress on economic development is 13.2% while the impact is 4.3% higher in eight selected East South Asian countries, at 13.5%, than in eight selected highly developed countries (9.2%).

Keywords
human development index, creation of technology, science and technology policy, technology achievement index, technological gap

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1. INTRODUCTION

1.1. Research Background

All economic schools of thought unanimously agree that the technological progress of the 18th century industrial revolution brought about substantial increases in productivity in the textile industry in the United Kingdom (UK). The concept of technological progress, then, is not new. The relationship between technological progress and economic growth and development became a subject of inquiry and the study of economics or political economy then formed as an organized discipline. A large number of economists have discussed the changes in output and production by the technological progress resulting from the Industrial Revolutions in the mid-eighteenth century. The role of technological progress in production or output commanded the attention of economists when Nobel laureate Robert Solow argued that technological change plays a vital role in total output/production and demonstrated that 87.5% of the increase in total output between the years 1909-1949 in the United States was the result of technical change (Solow, 1957). The pioneering work of Robert Solow provided new dimensions to our understanding of why countries such as the US and UK show persistent labor productivity growth, while others such as Niger and Zimbabwe become poor (Martínez-García, 2013).

After Solow's ground breaking paper (1957), numerous studies have been carried out by economists for whom the growth accounting approach was the dominant methodology for empirical measurements of productivity until early 1970s. As national accounting figures became available and statistical methodology became more refined, Solow's concept that technological progress accounts for all economic growth became less all-encompassing (Cameron, 1998). Economists and researchers agree that technological progress is a key element of factors of production and has a vital role in long-term economic growth and development. By utilizing the latest technologies, a firm, industry or country may enhance output with the same level of employment and capital. The use of new technologies in production and manufacturing, indeed, in every field of life, has been increasing rapidly since the last decade of the twentieth century. At the beginning of the twenty-first century, new inventions in the fields of agriculture, engineering, industrial engineering, biotechnology, pharmaceuticals, health, electronics, aeronautics and especially in information & communication technologies (ICT) have revolutionized the production process of firms in these industries as well as improving social wellbeing. In fact, technology can be regarded as a primary source in economic development, with the various technological changes contributing significantly to the development of underdeveloped countries. Technical progress contributes numerous ways including facilitating the use of potential resources and intensive utilization of resources, supporting exports, contributing to alternatives to imports, growth of infra-structure, increased efficiency of human resources, promoting industrialization, increase in capital formation, availability of foreign capital, agricultural development, and finally, positive change in social and economic structure.

1.2. Research Questions

It is clear that development in almost all advanced areas such as transportation, telecommunication, material resources and pharmaceuticals are based on science, technology and innovation (that is, technological progress). We can say that science, technology and innovation are omnipresent and universal in today's developed world. Technical progress plays a vital role in the economic development of any country. Although many countries in the world have limited ability and capacity to create new technologies, if they can adopt, absorb and disseminate available technologies then they can make significant economic gains compared with countries which lack these essential elements of the knowledge economy. Developing countries are full of natural resources, but they are unable to transform these into modern manufactured goods due to their lack of technological capability and capacity. If developing countries want to uplift their socioeconomic condition, they must shift to a knowledge based economy. As the role of technology advanced and its place in the production process and in our culture raised the concept of a knowledge based economy, it has become a vibrant area of research for economists, researchers, policy makers and planners. Such experts in the field grapple with questions like:

1. How can we measure the technological progress? Is it measureable by quantity?
2. What is the impact of technological progress on economic development?
3. Does a relationship exist between technological progress and economic development? If so, does this relationship affect economic development in both the short and long term?
4. What are the reasons that the technological gap between developed countries and developing countries is spreading rather than shrinking?

1.3. Objectives of Study

On the basis of these research questions, there are four major objectives of the present research:

a. To quantify the Technology Achievement Index (TAI) from 1995 to 2015 and rank countries on the basis of their TAI value.
b. To determine the technological achievement gap between countries from 1995-2015.
c. To re-calculate the Human Development Index (HDI) from 1995 to 2015 for smoothness.
d. To evaluate the overall impact of technological progress on economic development.

1.4. Brief Literature Review on Technological Progress Indicators

Different studies have been carried out to address how to quantify technological progress in terms of composite indicators, also referred to as science, technology, and innovation indicators (STIs). Some well-known STI composite indicators are: the WEF Technology Index (WEF, 2001; 2002; 2003; 2004; 2006), the National Innovative Capacity Index (NICI-03) (Porter & Stern, 2004), the Science and Technology Capacity Index 2002 (STCI-02) (Wagner, Horlings, & Dutta, 2002), the Technology Achievement Index (TAI-02) (Desai, Fukuda-Parr, Johansson, & Sagasti, 2002;

UNDP, 2001), the UNIDO Industrial Scoreboard (Lall & Albaladejo, 2003; UNIDO, 2003, 2004), the UNIDO Industrial-cum-Technological Advance Index (UNIDO, 2005), the New Indicator of Technological Capabilities for Developed and Developing countries (ArCO) (Archibugi & Coco, 2004), and the Georgia High Technology Indicators (TTI) (Porter, Roessner, Newman, Jin, & Johnson, 2006; Porter & Stern, 2004). Nasir, Ali, Shahdin, and Rahman, (2011) developed a technology achievement index referred as TAI-09, by applying the methodology of Desai, et al. (2002) in which they studied the existing technological capabilities and capacities of 91 countries.

Most of the studies carried out so far are about the technological performance of developed countries, while only a few studies discuss the developing countries. Studies with a limited geographical, organizational, or regional focus are almost non-existent; one exception being the Technology Achievement Index for Organization of Islamic Cooperation (OIC) member countries (referred as TAI-13-OIC) (Ali, Kiani, Asrar, & Bashir, 2014). Ali conducted another study, in which the Technology Achievement Index (TAI) for 41 of the OIC member states was presented (TAI-14-OIC). They concluded that though most of the OIC countries are rich in natural resources, they are unable to utilize them completely for their socio-economic development due to lack of scientific and technological capability (Ali, Bashir, & Kiani, 2015). Recently, Bashir (2015) developed the Global Science, Technology and Innovation Capacity index (GSTIC) based on nine pillars which reflect the national STI capacities of the countries: Technology creation, R&D capacity, R&D performance, technology absorption, diffusion of old technologies, diffusion of recent innovations, exposure to foreign technology, human capital, and enabling factors. Bashir ranked 167 countries with the GSTIC and categorized them into four groups: Leaders, dynamic adopters, slow adopters, and laggards (Bashir, 2015). The results show that there are large differences between nations in STI capacity, with developing countries far behind in some areas relative to developed nations.

Four of the indices mentioned, namely STCI-02, TAI-02, ArCO-04, and GSTIC, produce a nearly complete set of indicators for developing countries and are therefore more relevant for developing countries. However, the index which addresses the question of measurement of technological progress most specifically is the Technology Achievement Index (TAI). TAI is based on technology achievement for any country on a comparative scale, and focuses on assessing a country's technological performance based on its capability to create and use technology. The TAI provides information about weaknesses, strengths, and opportunities on a national basis.

1.5. Evaluating the Impact of Technological Achievement on Economic Development

Time series analysis is an appropriate method to evaluate long run impacts, and was utilized to seek the answers for the questions (1-4) raised in section 1. 2. The TAI and HDI were calculated for 21 years, from 1995 to 2015. The methodology and variables for HDI revised from time to time in the Human Development Report (HDR) issued by the United Nations Development Programme. Therefore, for smoothness, the HDI for 21 years was re-calculated from 1995 to 2015 for the top 100 economies of the world. The formulaic model used to investigate the impact of technological progress on economic development is:

$$HDI_{(t)} = F(K_{(t)}, TAI_{(t)})$$

Where the Human Development Index, HDI, is used as a dependent variable and the Technology Achievement Index (TAI) and Capital ($K_{(t)}$) are used as independent variables. HDI, TAI and Gross Capital Formation (GCF) are used as proxy variables for economic development, technological progress, and capital, respectively. STI policies play a significant role in building a knowledge-based economy and society in developing countries. It has been acknowledged that countries need to enhance their technological capabilities and capacities in order to remain globally competitive in the world economy. Therefore, technological achievement is always of interest for science and technology (S&T) planners, policy makers and economists. Policy makers in developing countries rely heavily on basic statistics of S&T to guide their Science, Technology and Innovation (STI) policies. Identifying technological achievement gaps is essential information for STI policy makers and planners to formulate better STI policies to address these gaps. The current study uses a standard deviation technique for this purpose.

1.6. Significance and Contribution of Study

This study has a wide range of implications for both research and real-world applications. It provides a new avenue for researchers, economists and STI planners to measure and assess technological progress. The study will also identify what causes a country to lag scientifically and technologically behind and consequently be economically underdeveloped. This paper gives strong evidence of the strength of the knowledge base economy concept and analyzes the weaknesses, strengths and opportunities of the STI system of countries not only at a national level, but also at an international level. This analysis equips policy makers and planners to formulate policies and allocate resources to advance the STI capacity of the country.

The indices discussed in literature review, including the WEF Technology Index (WEF, 2006), the National Innovative Capacity Index (NICI-03) (Porter & Stern, 2004), the Science and Technology Capacity Index 2002 (STCI-02) (Wagner et al, 2002), the New Indicator of Technological Capabilities for Developed and Developing countries (ArCO) (Archibugi & Coco, 2004), and the Georgia High Technology Indicators (TTI) (Porter et al., 2006), do not capture the technological achievement of the country as fully as the current study. Other studies such as Desai, et al. (2002), Nasir, et al. (2011), Ali, et al. (2015) and Bashir (2015) developed indices and presented ranking of countries, but they did not discuss the technological gap among different nations in as much detail as the present study. This study therefore represents a broader and more detailed approach than previous work on the subject.

This study is also innovative, presenting a new model for measuring the impact of technological progress on economic development of the country. We propose to verify through empirical evidence that economic development is linked with the technological preparedness of a country. Most developing countries are full of natural resources, but fail to transform these to the highest levels due to their lack of technological advancement. The results of this study may be used by policy makers to support policy measures and approaches that improve national competencies in order to compete with other nations in a global framework.

1.7. The Issue of Resource Allocation in Developing Countries and Policy Implications

The major issue for policy makers of developing countries is the failure to allocate resources to develop and enhance STI activities. Policy makers may in fact be unaware about the STI situation of their country due to a lack of STI empirical statistics. The current study addresses this issue by providing an exact and clear picture about the technological progress of the country. Policy makers can then seek guidelines to formulate the policies of their country, with a focus on accelerating the development of their technological capabilities. It is critical for developing countries to operate with a knowledge-based economy in order to be competitive in today's world economy.

2. THE TECHNOLOGY ACHIEVEMENT INDEX (TAI)

: An Instrument for Measuring National Readiness and Capacity to Participate in Global Knowledge Base Economy

2.1. Concept and Features

To understand the concept of TAI, it is necessary to understand the definition and meaning of "technology achievement." Technology achievement and technology progress are synonymous terms. There is no complete agreement on the definition of technology achievement. However, some important concepts are presented here. Desai, et al. (2002) wrote "technological achievement reflects the level of technological progress and thus the capacity of a country to participate in the network age." Nasir, et al. (2011) described that "the technology achievement of a country refers to the level of its technological readiness to participate in the global knowledge based economy (p. 41)." Ali, et al. (2014) argued that "the technological progress is the continuous process of improvement in total scientific knowledge, skill, applied science, and the technical efficiency and ability to convert the existing factor of production into more output, available to any human society for industry, art, science (p. 49)." It is clear that achievement and progress are synonyms in this context. By combining all these above mentioned concepts, I may define technology achievement as

> *the continuous overall process of improvement in total scientific knowledge, skill, applied science, the technical efficiency and invention, innovation and diffusion of technology or processes, level of its technological progress, readiness and the capacity of a country to participate in the network age and the global knowledge based economy*.

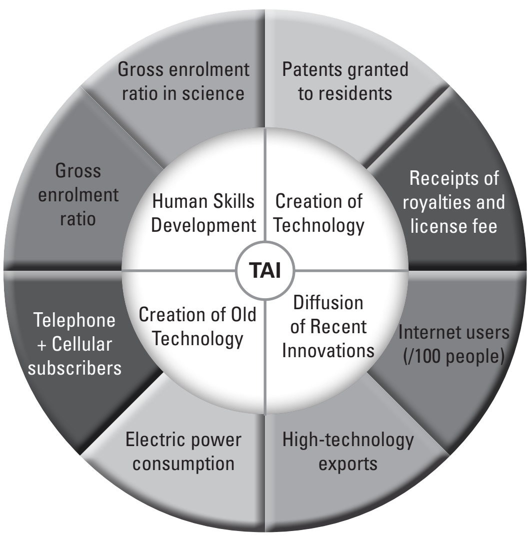
The question remains, how should technology achievement of a country be measured? It can be measured by the single composite Technology Achievement Index (TAI), which is based on different indicators and sub-indices, rather than using many different measures. This is similar to other composite indices such as the Human Development Index (HDI), Global Innovation Index (GII), and Global Competitiveness Index (GCI), which are used to measure the level of economic development, innovation and productivity, and prosperity of a country, respectively. *The Technology Achievement Index (TAI) is developed as a measure of a country's participation in creating and using technology. The TAI assesses the level of a country's technological progress, readiness and capacity to participate in the network age and the global knowledge-based economy. It also provides insight and awareness about weaknesses, strengths and opportunities at a national level.*

The TAI reflects a combination of relevant indicators along with input and output indicators. Input indicators measure the existing level of a country's technological ability, while output indicators may provide strong indication that the ability is dynamic and productive. A correct combination of these two gives a very realistic idea about the technology achievement level of a country. Nasir, et al. (2011) argued that "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 (p. 42)."

2.2. Composition of TAI

The TAI is composed of four dimensions which express the preparedness and capacity of the country to participate in a knowledge-based economy. Each dimension is comprised of two sub-indicators that are directly linked with the objectives of technology policy regardless of the level of development of a country. Although the details about these dimensions have already been discussed

FIGURE 1. The Four Dimensions of TAI



in the previous studies carried out by Desai, et al. (2002), Nasir, et al. (2011) and Ali, et al. (2014; 2015), a brief overview of the four main dimensions and their related sub indicators (Figure 1) is presented here.

2.2.1. Creation of Technology (ability to produce new inventions, innovations)

This dimension represents the innovative capacity of the country. Although it is not necessary for all countries to be on the leading edge of global technology development, the ability to innovate is pertinent for every country and is present in the highest level of technological competence (Desai, et al., 2002). Technological innovation is rewarded by the international economy. Every country requires competence to innovate; otherwise, it is unable to realize the new innovation in production process as per its local circumstances. Innovation capacity is measured by two indicators:

i) *Total patent grants (direct and PCT national phase entries)* that represent the stock of embedded knowledge and an indirect indicator of knowledge that has been developed and could be refined for future use. It also indicates the existing level of creative activity;
ii) *Charges for the use of intellectual property, receipts (BoP, current US$)* that represent the value of the use of stock of successful innovations already completed (WIPO, 2016; World Bank, 2016).

2.2.2. Diffusion of Recent Innovations (capacity to adopt and diffuse the new technologies)

This dimension indicates the ability to adopt and spread the recent innovation. If a nation has greater ability to adopt more technological goods, then it has a greater opportunity to participate in the global knowledge-based economy (Desai, et al., 2002). This dimension is measured by two indicators:

i) *Internet users (per 100 people)* is preferred over that of 'hosts,' as it provides a more exact representation of the spread of Internet use among the population. Widespread Internet use is a pre-requisite for participation in the world's economic activities; the Internet is one of the most active and dominant tools to access the global information at relatively low cost;
ii) *High-technology exports (% of manufactured exports)* is the best benchmark for measuring the annual average growth rates (AAGR) in a country with high levels of technology (World Bank, 2016).

2.2.3. Diffusion of Old Innovation (existing technologies that are basic inputs to the industrial and the network age)

The diffusion of old technologies like electricity, telephones, roads, railways, air and sea transportation, etc. are the basic ingredients for economic development of a country. Technological achievement is a cumulative process of increasing the use and scope of old technologies that is vital for embracing new innovations. For example, if you install a new machinery plant for production but do not have electricity to power it, in thus case electricity would be the basic ingredient (Desai, et al., 2002; Nasir, et al., 2011). This dimension is measured by two indicators:

i) *Electric power consumption (kWh/capita)* that provides a precise measurement of the diffusion of electricity within a society. The indicator is significant because of its use to power technology;
ii) *Fixed telephone + Mobile cellular subscriptions (per 100 people)* that indicates the participation in the communication revolution. Nations must adopt this innovation as a prerequisite to successful participation in the current IT network age (World Bank, 2016).

2.2.4. Human Skills Development (building a human skill base for technological creation and adoption)

A key element for all three dimensions is human skilled capital that is necessary for technological effectiveness. Both users and creators require skills. Basic education is the foundation of all types of skill sets that are indispensable for adoption, diffusion and creation of technology. It is not easy to define and measure these cognitive skill sets. A few attempts were made to create a cross-country comparison through the International Adult Literacy Survey (IALS) and the Trends in Mathematics and Science Study (TMSS), but these are limited in their scope, especially in developing countries (Desai, et al., 2002). It is better for our purposes to measure the quality of education rather than the quantity. So, this dimension is measured through two indicators:

i) *Gross Enrolment Ratio Primary to tertiary school, both sexes (%)* that is used to measure the overall level of basic educational achievement in the population, notwithstanding the fact that education quality varies from country to country;
ii) *Percentage of students in tertiary education enrolled in science, engineering, manufacturing and construction programmes* is used to gauge the quality of education. The indicator evaluates the current efforts in developing a skilled workforce in construction, engineering, mathematics and science at the tertiary level that possesses the skill base to adapt and innovate new technologies (UNESCO Institutes of Statistics/UIS, 2016).

2.3. Methodology for Developing TAI

First, the maximum and minimum values of the eight constituent's indicators are extracted from the compiled data in each country of interest for every year and a table of the goal posts for calculations is constructed.

Second, the values of the different indicators are standardized to a scale from 0 to 1 using goalposts, such that an indicator value that is equal to the upper goalpost will be normalized to 1 and a value equal to the lower goalpost will be normalized to 0, according to the formula given below:

$$\text{Indicators Index} = \frac{\text{Indicator Value of a Contury - Minimum Value of Indicator}}{\text{Maxium Value of a Indicator - Minimum Value of Indicator}}$$

Third, the index of each category is calculated by the same procedure used for the overall index; that is, the simple mean of sub-indicators. In the TAI, each dimension contains two indicators. The index for each dimension is calculated as the simple average of the indicator indices in that dimension. The TAI, in turn, is the simple average of these four dimensions' indices.

2.3.1. Weighting and Aggregation

An important issue is that of weighting of different indicators and dimensions. It is beyond the scope of this study to judge which indicators have a greater role in technological progress. The overall Technology Achievement Index (TAI) was built with the weighting of all four dimensions equally. The indicators in each dimension are given equal weight, and the dimensions are given equal (one-quarter) weight in the final index. This choice was based on the assumption that all four dimensions and components play a comparative role in the ranking of a country's technology achievement level.

2.3.2. Data Collection and Sources

It is difficult, expensive and time-consuming to collect the data and information for the eight indicators directly from data sources in every country in the world. For reasons of practicality, therefore, we rely in this study on the statistical publications and databases of major international organizations. The data have been taken primarily from reliable and highly trusted sources such as the Human Development Reports of the United Nations Development Programme (UNDP), databases of the UNESCO Institutes of Statistics (UIS), and publications of the World Bank (WB). Data from 1995 to 2015 of gross capital formation and TAI of countries have been retrieved from authenticated sources like World Bank, UNESCO, and WIPO. The indicators and their data sources have been illustrated in section 2.2.

2.3.3. Estimation of Missing Value for an Indicator

90% of the countries under study have data for more than six indicators, while 10% countries have data for less than five indicators. Data for the gross enrolment ratio in science (Tertiary), patent grants per million, and receipt of charges for the use of intellectual property are unavailable or missing for many countries (See Appendix 1.).

Two techniques (linear interpolation and forecasting) have been used to estimate missing values of individual indicators. Linear interpolation has been applied to estimate the missing data between two sets of data points. Missing data for year/s of an indicator between two years of available data were calculated in an Excel spreadsheet using the formula given below:

$$\text{Missing data} = \text{Previous year data} + \frac{(\text{Last year data} - \text{First year data})}{1 + \text{Numbers of year/s (you want to estimate)}}$$

Forecasting technique has been preferred for estimating future data values on based of present and past data values.

2.4. Ranking of Nations on the Basis of TAI Value

A Technology Achievement Index has been developed for 21 years from 1995 to 2015 for the top 100 economies for which data were available and of adequate quality, as shown in Table 1. Despite efforts to collect the data for eight indicators, data for patents and IP charges were not available for a number of nations in the developing world. A lack of data of any country might be assumed to represent that little formal innovation is taking place. Therefore, a value of zero for the missing indicator has been used for calculation purposes in such cases. Table 1 presents the Technology Achievement Index for 1995 and 2015 of 100 countries, and ranks of countries by the year 2015. The ranking and TAI value for other years is not presented here due to space limitations. The estimates of TAI are interesting and disappointing as well, as they illustrate the growth and limitations of the technology progress of nations. The TAI values show great disparities not only among the countries as a whole but also within the group of countries like developed and developing countries. The highest TAI value was 0.630 for the USA, while the lowest value was 0.065 for the Congo Republic. Following the procedure used in the TAI-02 (Desai et al., 2002), the countries have been classified based on their TAI values as:

i. Leaders (TAI > 0.425)
ii. Potential Leaders (0.350 ≤ TAI ≤ 0.424)
iii. Dynamic Adopters (0.200 ≤ TAI ≤ 0.349)
iv. Marginalized Countries (TAI<0.200)

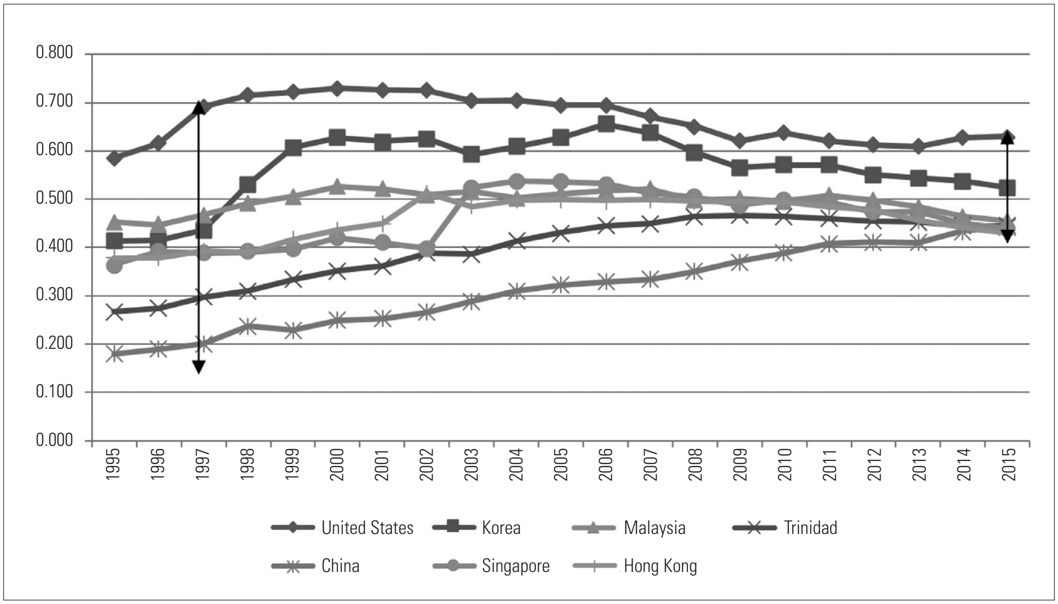
2.4.1. The Leaders (TAI > 0.425)

Although Nasir, et al. (2011) and Desai, et al. (2002) used a TAI value greater than 0.5 for leaders, we adopted a TAI value of 0.425 for leaders in the current study to capture the top 16 countries of the world. This group comprises sixteen countries which are highly developed and at the cutting edge of innovation, topped by the USA, Japan, and Korea in the 2015 rankings (Table 1).These countries have reached an excellent level of development of human skills and effectively diffused old technologies within their societies. They are leveraging recent technologies very well and can be described as being at the cutting edge of technological innovation, and consequently as leaders in science and technology, trade, industry and business (Ali, et al., 2015). In this group, the US and Japan seem to be successful in retaining their position from 1995 to 2015, while China, Trinidad, Singapore, the Republic of Korea, Hong Kong and Malaysia improved 69, 44, 17, 14 , 11 and 6 points respectively in their ranking thus able to successful to secure their place in the Leaders. Declines in the scores of Iceland, Netherlands, Sweden, Switzerland and Australia can be seen. The performance of China is particularly remarkable in terms of growth in technological achievement, with the greatest increase from 1995 to 2015 (Figure 2, Table 1).

2.4.2. Potential Leaders (0.350 ≤ TAI ≤ 0.424)

35 countries fall in this category. This group consists of both developed and fast developing countries which have invested in human skill development and used older technologies extensively, but are behind the Leaders in innovation. Countries of this group are weak in one or two dimensions

FIGURE 2. TAI Values (1995-2015): Reflecting Gap



like technology creation and recent innovation. Most of the countries in this group have similar skill levels as the Leader countries. Some countries show very good performance in technological achievement; for example, Oman, Vietnam, Kazakhstan, Qatar, Costa Rica and Lithuania improved 60, 58, 36, 28, 22 and 13 points during 21 years. Other countries like Finland, Ireland, UK, Belgium and Denmark ranked at 3, 4, 6, 15 and 16 respectively in 1995 could not retain their position and have fallen to the category of potential leaders in 2015 (Table 1).

2.4.3. Dynamic Adopters (0.200 ≤ TAI ≤ 0.349)

There are 35 countries included in this group, with Argentina at the top while Indonesia is at the bottom. A large number of developing countries are present in this group. They are speedily expanding their use of new technologies such as Internet and telecommunication (i.e., cellular mobile phone networks) which are imperative for high tech industries, but they are still behind in adopting and diffusing old technologies such as electricity, telephone, roads, railways, air and sea transportation which are the basic ingredients of technological development. Countries belonging to this group planned to utilize new technologies through a number of techniques. Among them, Brazil, Turkey, and India have developed significant high-technology industries and technology hubs. Apart from India, their human skill development level is considerable and continuing to improve further. India, Indonesia, and Brazil, the 2nd, 5th and 6th most populous countries in the world, are also in this category and were ranked at 75, 72, and 76 in 2015 (Table 1). These large and heavily populated countries need to spend heavily on human capital as well as investing in the diffusion of old technologies.

TABLE 1. Technology Achievement Index and Ranking (1995 and 2015)

1	2		3	
Country	2015		1995	
	Rank	Rank	Rank	TAI
The Leaders (TAI > 0.425)				
United States	1	0.630	1	0.585
Japan	**2**	**0.532**	**2**	**0.525**
Korea	**3**	**0.524**	**17**	**0.414**
Germany	4	0.465	13	0.433
Switzerland	5	0.461	10	0.462
Malaysia	**6**	**0.454**	**12**	**0.453**
France	7	0.449	11	0.455
Trinidad	8	0.445	51	0.267
China	**9**	**0.443**	**78**	**0.179**
Netherlands	10	0.441	7	0.477
Singapore	11	0.440	28	0.365
Iceland	12	0.437	5	0.507
Sweden	13	0.435	8	0.474
Norway	14	0.434	9	0.465
Hong Kong	15	0.429	26	0.378
Australia	16	0.425	14	0.427
Potential Leaders (0.275 ≤ TAI ≤ 0.424)				
Oman	17	0.422	77	0.179
Austria	18	0.422	19	0.400
UAE	19	0.412	34	0.326
Luxembourg	20	0.412	21	0.395
Kazakhstan	21	0.410	57	0.233
Finland	22	0.408	3	0.513
UK	23	0.407	6	0.493
Denmark	24	0.407	16	0.425
Qatar	25	0.407	53	0.258
Ireland	26	0.402	4	0.507
Vietnam	27	0.401	85	0.156
Belgium	28	0.400	15	0.426
Czech	29	0.396	23	0.387
New Zealand	30	0.395	20	0.398
Israel	31	0.389	22	0.394
Chile	32	0.383	46	0.285
Bahrain	33	0.383	32	0.334
Latvia	34	0.376	47	0.282
Slovenia	35	0.373	27	0.365
Spain	36	0.373	24	0.384
Slovak Rep.	37	0.370	29	0.363
South Africa	51	0.351	60	0.232
Dynamic Adopters (0.200 ≤ TAI ≤ 0.349)				
Argentina	52	0.342	44	0.291
Croatia	53	0.341	39	0.312
Ecuador	54	0.338	74	0.197
Venezuela	55	0.336	54	0.253
Bulgaria	56	0.336	38	0.312
Philippines	57	0.333	52	0.264
Lebanon	58	0.333	40	0.311
Romania	59	0.327	58	0.233
Mexico	60	0.323	35	0.325
Azerbaijan	61	0.316	66	0.222
Cyprus	62	0.313	36	0.323
Serbia	63	0.313	59	0.233
Thailand	64	0.311	48	0.280
Kenya	65	0.305	84	0.159
Saudi Arabia	66	0.305	71	0.215
Panama	67	0.304	61	0.231
Cuba	68	0.297	45	0.290
Colombia	69	0.294	50	0.267
Tunisia	70	0.290	68	0.218
Macao SAR	71	0.287	70	0.218
Brazil	72	0.278	72	0.212
Algeria	73	0.271	92	0.126
Jordan	74	0.269	75	0.186
India	**75**	**0.259**	**93**	**0.115**
Morocco	76	0.248	76	0.185
Turkey	77	0.247	65	0.224
El Salvador	78	0.244	64	0.229
Sri Lanka	**79**	**0.235**	**91**	**0.132**
Puerto Rico	80	0.232	79	0.174
Dominican	81	0.232	82	0.160
Iran	82	0.226	63	0.229
Egypt	83	0.221	88	0.142
Peru	84	0.220	80	0.170
Uzbekistan	85	0.219	56	0.244
Indonesia	86	0.215	89	0.141
Marginalized Countries (TAI<0.200)				
Syria	87	0.193	86	0.148

Russia	38	0.370	41	0.304
Belarus	39	0.370	33	0.326
Uruguay	40	0.368	49	0.273
Hungary	41	0.364	30	0.358
Kuwait	42	0.360	42	0.293
Greece	43	0.359	31	0.348
Canada	44	0.358	25	0.378
Portugal	45	0.357	37	0.323
Poland	46	0.356	43	0.291
Costa Rica	47	0.356	69	0.218
Italy	48	0.355	18	0.405
Lithuania	49	0.355	62	0.230
Ukraine	50	0.352	55	0.252

Libya	88	0.189	83	0.159
Guatemala	89	0.181	81	0.166
Cameroon	90	0.141	90	0.134
Pakistan	91	0.141	67	0.222
Iraq	92	0.139	87	0.143
Cote d'Ivoire	93	0.139	73	0.206
Bangladesh	94	0.136	96	0.063
Nigeria	95	0.135	99	0.048
Sudan	96	0.130	100	0.039
Ethiopia	97	0.098	97	0.058
Yemen	98	0.080	95	0.084
Tanzania	99	0.079	94	0.100
Congo	100	0.065	98	0.056

2.4.4. Marginalized Countries (TAI<0.200)

This group consists of 14 countries with Syria at the top and the Congo Republic at the bottom (Table 1). The countries in this group are not only weak in technology creation and diffusion of recent innovation, but also in human skill development and the use and spread of old technologies. Large parts of the population in these countries are deprived of basic necessities like electricity, health, clean water, and telecommunication. Pakistan, Nigeria and Bangladesh, with the 6th, 7th and 8th largest population in the world are especially low in the dimension of human skill development, which is a major impediment their economic growth and contribution to the global knowledge-based economy. This group of countries would need to invest heavily in the education sector in order to improve their human skills level. Better attention for the diffusion of old technologies is also advisable for marginalized countries.

2.5. Calculation of Technological Gap and Shifts in the Technological Capability Spread

In order to examine the trends in the spread of countries' technological capability, a Standard Deviation (SD) technique has been adopted. The Standard Deviation of the TAI values of different groups of countries for the year 1995, 2005, 2010, and 2015 are calculated and shown in Table 2-8. The SD indicates the spread of data points around the mean value. The SD of TAI values' data points are used as proxies for the S & T capability of nations. A low SD value indicates less dispersion, while a high value shows the reverse (high dispersion), both of these over a specific period that represents the rise and fall in the S&T capability of countries. Table 2 shows the SD values of the top 100 world economies. In 2000, the SD value is high (0.143); although it seems to have declined in 2005, 2010, and 2015 it is still stagnant. This indicates that technological gaps were high at the beginning of the 21st century; although the gap is lessening gradually it has not completely vanished.

TABLE 2. Standard Deviation Calculation of TAI Values for Top 100 Economies (1995-2015)

	1995	2000	2005	2010	2015	%Change
SD	0.1075	0.1430	0.1394	0.1219	0.1079	0.3804
VAR	0.0154	0.0205	0.0194	0.0148	0.0116	
Mean	0.2805	0.3310	0.3463	0.3568	0.3263	
Median	0.2670	0.3290	0.3424	0.3711	0.3517	
Sum	28.0485	33.0977	34.6345	35.6765	32.6269	

**SD: Standard Deviation, VAR: Variance*

TABLE 3. Standard Deviation Calculation of TAI Values for 16 Leaders Countries (1995-2015)

	1995	2000	2005	2010	2015	%Change
SD	0.0978	0.1147	0.0856	0.0602	0.0535	-45.2637
VAR	0.0096	0.0132	0.0073	0.0036	0.0029	
Mean	0.4290	0.5168	0.5342	0.5146	0.4652	
Median	0.4537	0.5282	0.5373	0.5077	0.4437	
Sum	6.8645	8.2688	8.5479	8.2343	7.4433	

TABLE 4. Standard Deviation Calculation of TAI Values for 35 Potential Leaders Countries (1995-2015)

	1995	2000	2005	2010	2015	%Change
SD	0.0876	0.0942	0.0805	0.0529	0.0230	-73.7625
VAR	0.0077	0.0089	0.0065	0.0028	0.0005	
Mean	0.3353	0.3883	0.4053	0.4124	0.3823	
Median	0.3338	0.4053	0.4229	0.4110	0.3760	
Sum	11.7343	13.5918	14.1870	14.4346	13.3816	

TABLE 5. Standard Deviation Calculation of TAI Values for 35 Dynamic Adopters Countries (1995-2015)

	1995	2000	2005	2010	2015	%Change
SD	0.0597	0.0638	0.0609	0.0554	0.0425	-28.8076
VAR	0.0036	0.0041	0.0037	0.0031	0.0018	
Mean	0.2236	0.2658	0.2857	0.3120	0.2845	
Median	0.2236	0.2555	0.2808	0.3003	0.2937	
Sum	7.8246	9.3019	10.0003	10.9198	9.9573	

TABLE 6. Standard Deviation Calculation of TAI Values for 16 Marginalized Countries (1995-2015)

	1995	2000	2005	2010	2015	%Change
SD	0.0603	0.0627	0.0493	0.0522	0.0400	-33.6994
VAR	0.0036	0.0039	0.0024	0.0027	0.0016	
Mean	0.1161	0.1382	0.1357	0.1491	0.1318	
Median	0.1168	0.1371	0.1352	0.1479	0.1372	
Sum	1.6251	1.9351	1.8993	2.0877	1.8447	

TABLE 7. Standard Deviation Calculation of TAI Values for 34 OECD Countries (1995-2015)

	1995	2000	2005	2010	2015	%Change
SD	0.0792	0.0989	0.0833	0.0695	0.0660	-16.7295
VAR	0.0063	0.0098	0.0069	0.0048	0.0044	
Mean	0.9923	1.1599	1.1777	1.1349	0.9905	
Median	0.4024	0.4866	0.4801	0.4701	0.4013	
Sum	13.8923	16.2391	16.4883	15.8881	13.8671	

TABLE 8. Standard Deviation Calculation of TAI Values for 66 Non OECD Countries (1995-2015)

	1995	2000	2005	2010	2015	%Change
SD	0.0851	0.0957	0.1042	0.1024	0.1012	19.0221
VAR	0.0072	0.0091	0.0109	0.0105	0.0103	
Mean	1.0112	1.2042	1.2962	1.4135	1.3400	
Median	0.2199	0.2509	0.2717	0.3141	0.3044	
Sum	14.1561	16.8587	18.1463	19.7885	18.7598	

The SD values of the TAI of leaders, potential leaders, dynamic adopters and marginalized countries are represented in Table 3, 4, 5 and 6 respectively. A very simple formula has been adopted to find out the percent change in SD value in the different group of the countries:

$$Precent\ Change\ (\%) = \frac{Present\ value\ -\ Past\ value}{Past\ value} * 100\downarrow$$

Shrinkage in the TAI values of leaders, potential leaders, dynamic adopters and marginalized countries were 45.2%, 73.7%, 28.8%, and 33.6% respectively from 1995 to 2015, showing the results of the efforts of the countries in these groups to bridge the S&T capability gap rapidly. However, potential leaders are showing great potential to close up the technological gap as compared to other groups because it has highest value of percent change (73.7%). The analysis is interesting if we break up the 100 countries into OECD and non-OECD countries. Tables 7 and 8 show the results of SD analysis for 34 OECD (except Estonia) and 66 Non-OECD countries. While the shrinkage in SD of TAI values for OECD countries over 1995–2015 is almost 16.7%, in the case of non-OECD countries on the contrary an increase in the SD values of around 19% over the same period is found. The results of this very simple technique endorse the fact that OECD countries are quick to grasp the role and importance of S&T, while the capacity of non-OECD countries that are already lagging behind in S&T development leaves much to be desired.

Using the standard deviation of TAI values as an instrument to evaluate the technological readiness of nations appears to be working reasonably well. However, at this stage, we will perform a more detailed analysis. We have already described in the methodology section how the maximum level of technological achievement is 1 and the minimum is zero. The technological gap may also be calculated as:

Technological Gap = 1 - TAI value of a country

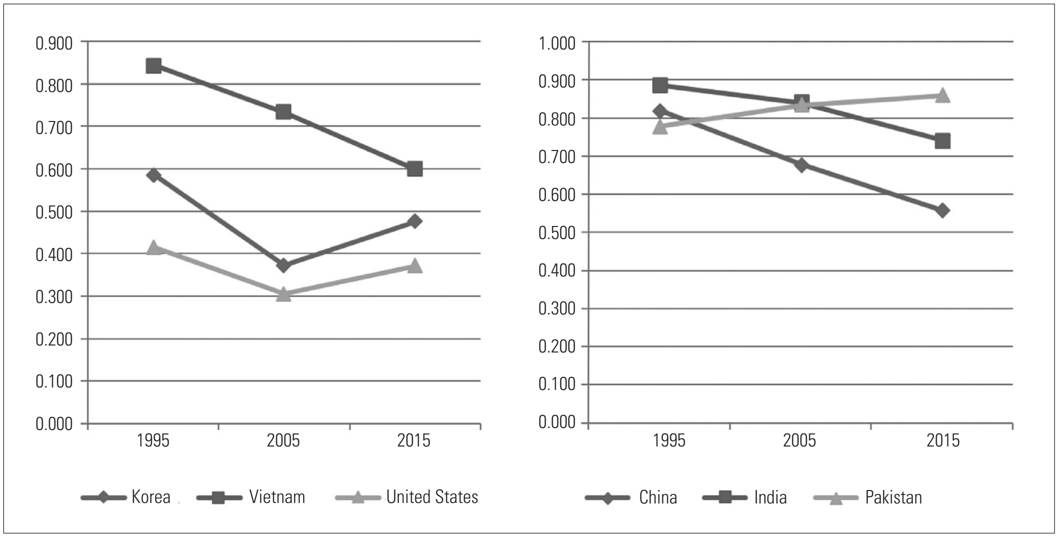
TABLE 9. Technological Achievement Gap Value

S#	Country	1995	2005	2015
1	Algeria	0.874	0.784	0.729
2	Argentina	0.709	0.670	0.658
3	Australia	0.573	0.518	0.575
4	Austria	0.600	0.520	0.578
5	Azerbaijan	0.778	0.756	0.684
6	Bahrain	0.666	0.657	0.617
7	Bangladesh	0.937	0.868	0.864
8	Belarus	0.674	0.619	0.630
9	Belgium	0.574	0.516	0.600
10	Brazil	0.788	0.734	0.722
11	Bulgaria	0.688	0.616	0.664
12	Cameroon	0.866	0.832	0.859
13	Canada	0.622	0.569	0.642
14	Chile	0.715	0.603	0.617
15	China	0.821	0.679	0.557
16	Colombia	0.733	0.690	0.706
17	Congo	0.944	0.917	0.935
18	Costa Rica	0.782	0.658	0.644
19	Cote d'Ivoire	0.794	0.818	0.861
20	Croatia	0.688	0.627	0.659
21	Cuba	0.710	0.716	0.703
22	Cyprus	0.677	0.611	0.687
23	Czech	0.613	0.520	0.604
24	Denmark	0.575	0.484	0.593
25	Dominican	0.840	0.778	0.768
26	Ecuador	0.803	0.745	0.662
27	Egypt	0.858	0.815	0.779
28	El Salvador	0.771	0.717	0.756
29	Ethiopia	0.942	0.956	0.902
30	Finland	0.487	0.461	0.592
31	France	0.545	0.485	0.551
32	Germany	0.567	0.452	0.535
33	Greece	0.652	0.588	0.641
34	Guatemala	0.834	0.788	0.819
35	Hong Kong	0.622	0.501	0.571
51	Latvia	0.718	0.603	0.624
52	Lebanon	0.689	0.680	0.667
53	Libya	0.841	0.807	0.811
54	Lithuania	0.770	0.605	0.645
55	Luxembourg	0.605	0.551	0.588
56	Macao SAR	0.782	0.728	0.713
57	Malaysia	0.547	0.489	0.546
58	Mexico	0.675	0.608	0.677
59	Morocco	0.815	0.757	0.752
60	Netherlands	0.523	0.441	0.559
61	New Zealand	0.602	0.534	0.605
62	Nigeria	0.952	0.886	0.865
63	Norway	0.535	0.480	0.566
64	Oman	0.821	0.773	0.578
65	Pakistan	0.778	0.833	0.859
66	Panama	0.769	0.702	0.696
67	Peru	0.830	0.766	0.780
68	Philippines	0.736	0.623	0.667
69	Poland	0.709	0.635	0.644
70	Portugal	0.677	0.569	0.643
71	Puerto Rico	0.826	0.776	0.768
72	Qatar	0.742	0.655	0.593
73	Romania	0.767	0.645	0.673
74	Russia	0.696	0.643	0.630
75	Saudi Arabia	0.785	0.730	0.695
76	Serbia	0.767	0.641	0.687
77	Singapore	0.635	0.464	0.560
78	Slovak Rep.	0.637	0.541	0.630
79	Slovenia	0.635	0.576	0.627
80	South Africa	0.768	0.738	0.649
81	Spain	0.616	0.528	0.627
82	Sri Lanka	0.868	0.785	0.765
83	Sudan	0.961	0.921	0.870
84	Sweden	0.526	0.446	0.565
85	Switzerland	0.538	0.461	0.539

36	Hungary	0.642	0.562	0.636	86	Syria	0.852	0.827	0.807
37	Iceland	0.493	0.432	0.563	87	Tanzania	0.900	0.862	0.921
38	**India**	0.885	0.840	0.741	88	Thailand	0.720	0.662	0.689
39	Indonesia	0.859	0.729	0.785	89	Trinidad	0.733	0.569	0.555
40	Iran	0.771	0.676	0.774	90	Tunisia	0.782	0.708	0.710
41	Iraq	0.857	0.883	0.861	91	Turkey	0.776	0.731	0.753
42	Ireland	0.493	0.486	0.598	92	UAE	0.674	0.577	0.588
43	Israel	0.606	0.555	0.611	93	UK	0.507	0.474	0.593
44	Italy	0.595	0.546	0.645	94	Ukraine	0.748	0.646	0.648
45	**Japan**	0.475	0.355	0.468	95	United States	0.415	0.306	0.370
46	Jordan	0.814	0.719	0.731	96	Uruguay	0.727	0.664	0.632
47	Kazakhstan	0.767	0.759	0.590	97	Uzbekistan	0.756	0.795	0.781
48	Kenya	0.841	0.750	0.695	98	Venezuela	0.747	0.691	0.664
49	**Korea**	0.586	0.373	0.476	99	Vietnam	0.844	0.733	0.599
50	Kuwait	0.707	0.662	0.640	100	Yemen	0.916	0.904	0.920

With this formula, the country with the highest technological gap value has the lowest achievement level, while the country that obtains the technological gap value has the highest level of achievement.

FIGURE 3. Rise and Fall in Technological Gap of Some Countries



The calculated technological gap value of 100 countries for the years 1995, 2010 and 2015 are shown in Table 9. Figure 3 represents the technological gap of Vietnam, Korea, US, China, India, and Pakistan. It clearly indicates that Vietnam and China sharply lowered their gap while in case of Pakistan, it was increasing continuously from 1995-2015. Pakistan must work hard to reduce its technological gap value. The USA and Korea are moving in a similar fashion. They are at their maximum level of achievement in 2005, but could not successfully maintain their tempo from 2005 to 2015. Table 9 illustrates the rank order of the countries for their technological gap values.

3. THE HUMAN DEVELOPMENT INDEX (HDI)

: An Instrument for Measuring Human Development

3.1. Concept and Design

HDI is commonly considered a valid yardstick to measure economic development of countries. The HDI was created so that a focus on people and their capabilities would be the ultimate criteria for assessing the development of a country, and not economic growth alone. The HDI can also be used to question national policy choices, asking how two countries with the same level of GNI per capita can end up with different human development outcomes (UNDP, 2015). The HDI is an aggregate measure of achievement in key components of human development: A long and healthy life, being knowledgeable, and having a decent standard of living. The HDI is the average mean of normalized indices for each of these three dimensions. The health, education and standard of living dimensions are measured by life expectancy at birth, mean of years of schooling for adults aged 25 years and more and expected years of schooling for children, and gross national income per capita respectively.

3.2. Calculation of the Human Development Index

The HDI has been calculated and published in the form of a Human Development Report (HDR) every year by the UNDP since 1990. There are, however, variations in its methodology and in the indicators used. Therefore, we decided to re-calculate the HDI for the current study for 21 years (from 1995-2015) with same three dimensions and indicators as given in the Human Development Report (HDR) 2015 with one slight modification to their formula. They used the geometric mean of indices of three dimensions as given below:

$$HDI = (I_{Health} + I_{Education} + I_{Income})^{1/3}$$

There is a drawback in this formula. If the value of one dimension index is zero while the other two dimensions' indices values are 0.6 and 0.4, then the overall HDI would still be zero. So, it may not always accurately reflect the overall development of a country. Therefore, it is most suitable to use the average mean rather than the geometric mean as applied in previous reports like the HDR 2002 (UNDP, 2002).

$$HDI = (I_{Health} + I_{Education} + I_{Income}) / 3$$

The current study calculates the HDI by following the methodology given in the technical notes of the HDR 2015 with the exception of the above formula.[1]

3.3. Ranking Nations on the Basis of HDI Value

HDI has been computed every year since 1990, and measured average achievements in basic human development with a simple composite index and produces a ranking of countries. The concept of human development is much deeper and richer than what can be captured in any composite index or even in a detailed set of statistical indicators. Yet, simple tools are needed to monitor progress in human development (UNDP, 2000). The HDI Value indicates the distance that a country has to voyage to reach the maximum possible value of 1 and also permits inter-country comparisons. It provides insight for every country to seek ways to boost its index by way of investment in the respective areas. The recalculated Human Development Index (HDI) of the top 100 economies is shown in Table 10. Countries are ranked by the 2015 HDI value; the HDI values and ranking for 1995 are also presented. In 1995, Australia, Norway, United States, Canada, and Switzerland stood at the top of the HDI rankings and were ranked as first through fifth positions respectively, while Ethiopia, Yemen, Congo and Niger were ranked at the bottom of the HDI, in the 100th, 99th, 98th, and 97th positions. Australia and Norway have successfully maintained their positions since 1995, while the United States moved down one (from 8th to 9th) and Canada up one place (from 14th to 13th) between 1995 and 2015. Improvement has been seen in 43 countries out of 100 since 1995, while 57 countries earned a lower ranking. The countries are classified into four groups on the basis of their HDI value which we will explain next.

3.3.1. Very High Human Development (HDI value ≥ 0.800)

An HDI value greater than or equal to 0.800 is set as the standard for "very high human development" by the HDR-2015 (UNDP, 2015). Of the 100 countries for which the HDI is available as shown in Table 10, 25 are in the "very high human development" category (with an HDI value equal to or more than 0.800). Australia and Norway lead this group, with Finland and Slovenia at the bottom. The countries belonging to this group are excellent in all three dimensions of the HDI (i.e., a long and healthy life index, living standard index and education index.) Most of the countries are European, with Korea Republic and Japan placing in this group as well (Table 10).

3.3.2. High Human Development (0.700 ≤ HDI value ≤ 0.790)

14 countries were placed in the "high human development" category (0.700–0.790) according to their ranking in 2015. Qatar and Greece are at the head of this category and Poland and Kuwait are at the foot (Table 10). These countries are better performers in one or two of the indices rather than overall. For example, Qatar has a very high gross national income (GNI) per capita but scores relatively low in education.

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[1] Life expectancy at birth (UNDESA, 2015), Mean years of schooling (UNESCO Institute for Statistics, 2015 and Human Development Report), Expected years of schooling (UNESCO, 2015), Gross national income per capita (World Bank, 2015).

TABLE 10. Human Development Index (HDI) (1995 and 2015)

1	2		3	
Country	2015		1995	
	Rank	Value	Rank	Value
Very High Human Development				
Australia	1	0.906	1	0.900
Norway	2	0.888	2	0.883
Switzerland	3	0.872	3	0.877
Singapore	4	0.866	4	0.863
Netherlands	5	0.860	6	0.855
New Zealand	6	0.857	5	0.856
Ireland	7	0.853	7	0.850
Macao SAR	8	0.845	11	0.836
United States	9	0.842	8	0.842
Hong Kong	10	0.840	9	0.838
Germany	11	0.839	10	0.837
Korea	**12**	**0.834**	**15**	**0.828**
Canada	13	0.834	14	0.830
Sweden	14	0.834	13	0.834
Denmark	15	0.828	16	0.823
Italy	16	0.826	12	0.836
Japan	**17**	**0.825**	**17**	**0.820**
Israel	18	0.820	19	0.815
UK	19	0.817	18	0.818
France	20	0.816	20	0.814
Spain	21	0.811	22	0.807
Belgium	22	0.806	21	0.807
Austria	23	0.805	23	0.804
Finland	24	0.804	24	0.801
Slovenia	25	0.801	25	0.799
High Human Development				
Qatar	26	0.790	27	0.786
Greece	27	0.776	28	0.781
UAE	28	0.775	26	0.791
Czech Rep.	29	0.774	29	0.772
Cyprus	30	0.753	30	0.753
Puerto Rico	31	0.751	31	0.751
Chile	32	0.742	33	0.737
Portugal	33	0.740	32	0.737
Slovak Rep.	34	0.732	34	0.732
Lithuania	35	0.732	35	0.730
Saudi Arabia	36	0.726	36	0.719
Bahrain	37	0.711	37	0.708

1	2		3	
Country	2015		1995	
	Rank	Value	Rank	Value
Kazakhstan	51	0.654	52	0.641
Lebanon	52	0.649	50	0.647
Turkey	53	0.646	55	0.637
Russia	54	0.643	54	0.639
Panama	55	0.639	56	0.635
Iran	56	0.639	58	0.631
Serbia	57	0.631	57	0.634
Malaysia	**58**	**0.629**	**60**	**0.620**
Mexico	59	0.626	59	0.623
Ecuador	60	0.621	53	0.641
Trinidad	61	0.617	62	0.615
Brazil	62	0.605	63	0.604
Algeria	63	0.601	64	0.598
Dominican	64	0.601	61	0.619
Ukraine	65	0.598	67	0.594
Peru	66	0.597	68	0.590
Jordan	67	0.596	66	0.595
China	**68**	**0.593**	**69**	**0.587**
Azerbaijan	69	0.589	72	0.579
Libya	70	0.580	65	0.596
Iceland	71	0.578	73	0.579
Thailand	72	0.578	74	0.578
Tunisia	73	0.574	70	0.582
Colombia	74	0.562	76	0.561
Morocco	75	0.552	71	0.580
Luxembourg	76	0.538	77	0.532
Guatemala	77	0.533	75	0.562
Egypt	78	0.518	78	0.523
Philippines	79	0.510	79	0.519
Indonesia	80	0.501	80	0.498
El Salvador	81	0.500	81	0.497
Low Human Development				
Argentina	82	0.488	82	0.486
Vietnam	83	0.485	83	0.483
Uzbekistan	84	0.477	84	0.473
Sri Lanka	**85**	**0.447**	**85**	**0.444**
South Africa	86	0.439	86	0.432
India	**87**	**0.400**	**87**	**0.393**
Bangladesh	**88**	**0.396**	**88**	**0.389**

Poland	38	0.709	40	0.691
Kuwait	39	0.702	38	0.703
Medium Human Development				
Latvia	40	0.693	41	0.690
Cuba	41	0.690	39	0.697
Belarus	42	0.681	43	0.671
Venezuela	43	0.681	42	0.680
Croatia	44	0.681	46	0.665
Uruguay	45	0.673	44	0.670
Hungary	46	0.670	51	0.645
Bulgaria	47	0.666	47	0.660
Romania	48	0.665	48	0.659
Oman	49	0.663	45	0.666
Costa Rica	50	0.655	49	0.651

Pakistan	89	0.323	89	0.320
Kenya	90	0.307	91	0.302
Syria	91	0.306	90	0.313
Tanzania	92	0.306	92	0.294
Iraq	93	0.266	94	0.265
Niger	94	0.265	93	0.294
Sudan	95	0.244	95	0.244
Cameroon	96	0.235	96	0.230
Ethiopia	97	0.203	97	0.194
Yemen, Rep.	98	0.155	98	0.154
Cote d'Ivoire	99	0.151	99	0.147
Congo	100	0.119	100	0.115

3.3.3. Medium Human Development (0.500 ≤ HDI value ≤ 0.690)

The highest numbers of countries (42) are placed in the "medium human development" category ranging from 0.699 to 0.500. Latvia and Cuba are leading in front, with HDI values of 0.693 and 0.690 respectively while Indonesia and El Salvador are at the bottom of this category (Table 10). Most of the countries are in this category are in the African and South East Asian subcontinent.

3.3.4. Low Human Development (HDI value <0.500)

The "low human development" category consists of 19 countries which have an HDI value of less than 0.500. Argentina and Vietnam are on top of this category with HDI values of 0.488 and 0.485, and the Congo is at the lowest position with its value of 0.119, the lowest score of any of the countries ranked on human development (Table 10). Highly populated countries of the world like India, Pakistan, Bangladesh, Vietnam, and Ethiopia are found under this category.

3.4. Trends in Human Development, 1995-2015

Some changes seen between 1995 and 2015 bear remarking upon. Ethiopia earned a higher HDI value in 2015 than in 1995. Ethiopia successfully improved its HDI from 1995 to 2015, but then slid back, placing in the low human development countries list because of their low life expectancy. Even though 42 out of 100 countries enhanced the basic capabilities of their people in some way in the period of 1995–2015, the specifics varied.

The rate of progress improvement in human development was different among countries, as shown in Table 11. In each human development group (very high, high, medium and low), there were countries which were fast in their progress in improving the human development factors, while others were slow in their progress or even declined. Figures reflecting the speed of progress of human development are presented in Table 11.

TABLE 11. Fastest, Slowest, and Decline in Progress in Human Development, 1995–2015

For top 100 economies for which HDI calculated

	Country	Human Development Index		Absolute Change
		2015	1995	1995-2015
Very High Human Development (HDI value ≥ 0.800)				
Fastest in progress	Macao SAR, China	0.845	0.592	0.252
	Singapore	0.866	0.775	0.091
	Korea	0.834	0.767	0.067
Slowest in progress	Switzerland	0.872	0.869	0.003
	New Zealand	0.857	0.856	0.001
	Denmark	0.828	0.828	0.000
Decline in progress	Sweden	0.834	0.868	-0.034
	Canada	0.834	0.872	-0.038
	Belgium	0.806	0.845	-0.039
High Human Development (0.700 ≤ HDI value ≤ 0.790)				
Fastest in progress	Saudi Arabia	0.726	0.643	0.083
	Slovak Rep.	0.732	0.667	0.065
Slowest in progress	UAE	0.775	0.773	0.002
	Portugal	0.740	0.739	0.001
Decline in progress	Bahrain	0.711	0.761	-0.051
	Puerto Rico	0.751	0.816	-0.066
Medium Human Development (0.500 ≤ HDI value ≤ 0.690)				
Fastest in progress	Belarus	0.681	0.571	0.110
	Morocco	0.552	0.453	0.099
	Turkey	0.646	0.563	0.084
Slowest in progress	Brazil	0.605	0.598	0.008
	Croatia	0.681	0.675	0.006
	Oman	0.663	0.661	0.002
Decline in progress	Lebanon	0.649	0.698	-0.049
	Serbia	0.631	0.692	-0.060
	Libya	0.580	0.647	-0.067
Low Human Development (HDI value <0.500)				
Fastest in progress	Ethiopia	0.203	0.034	0.169
	Tanzania	0.306	0.213	0.093
Slowest in progress	Sri Lanka	0.447	0.440	0.007
	Argentina	0.488	0.486	0.002
Decline in progress	Cote d'Ivoire	0.151	0.240	-0.089
	South Africa	0.439	0.560	-0.121

Improvement in human development is not only an issue of long-term progress. The association between economic riches and human development is neither automatic nor clear. Two countries which have similar incomes but have very different HDI values are presented in Figure 4, while two countries with similar HDI values can have very different incomes (Table 12). Figure 4 is a symbolic graphical representation (without proportional y-axis and x-axis scales). There are many other factors involved in the development of countries, of course, but we will choose our focus for our purposes. Figure 4 shows that South Africa has similar GNI per capita compared with Serbia, but it has been less successful in translating this economic prosperity into better lives for their citizens. On the other hand, the UAE, which has three times less GNI per capita than Greece, has achieved the same value of HDI with Greece, suggesting that it has used its income to promote human development very effectively (Table 12).

FIGURE 4. Similar Income, Different Human Development (2015)

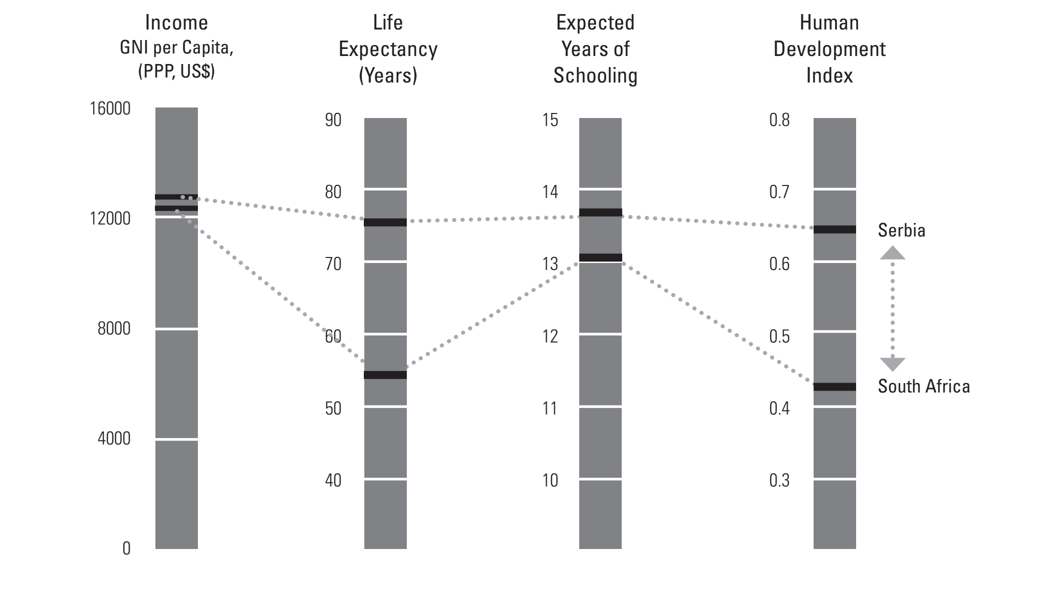
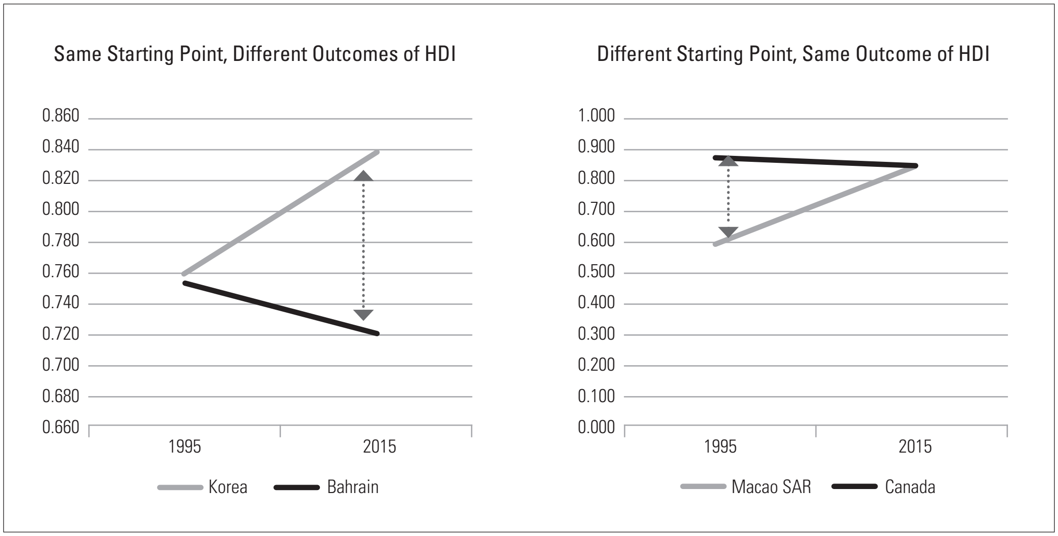


TABLE 12. Similar HDI, Different Incomes (GNI per capita), 2015

Country	HDI Value	GNI per capita, PPP *
Australia	0.906	42631.018
Norway	0.888	65836.500
Korea	0.834	34677.024
Canada	0.834	42579.683
Greece	0.776	22565.556
UAE	0.775	8182.986
South Africa	0.439	12184.502
India	0.400	5649.449

** (constant 2011 international $)*

FIGURE 5. Different Patterns of Development



Countries that begun with the same HDI values in 1995 may have finished with very different ones in 2015, while countries having very different beginning points in 1995 may have ended up with similar HDI values in 2015 (Figure 5). These changes result from a combination of different factors, but the policies countries pursued are a major determinant (UNDP, 2000).

4. THE BASIC MODEL FOR MEASURING THE IMPACT OF TECHNOLOGICAL PROGRESS ON ECONOMIC DEVELOPMENT

4.1. The Model Specification (Description of Variables and their Justification)

The last and final objective of the study is to evaluate the effect of technological progress on the social wellbeing of a nation's people (in terms of economic development). Although there are many exogenous and endogenous factors that impact on HDI, the current study takes the assumption of ceteris paribus (other things held constant). The TAI is an aggregate of eight indicators or variables, while the HDI is an aggregate of four indicators. For this purpose we have estimated the TAI and HDI values for the 21 year span from 1995 to 2015 for the top 100 economies of the world to facilitate the time series analysis. The HDI is used as a dependent variable, serving as a proxy for economic development, while the Gross Capital Formation (GCF) and TAI have been used as independent variable proxies for capital and technological progress respectively in the model given below:

$$HDI_{(t)} = F(K_{(t)}, TAI_{(t)})$$

Expanding both sides, the above equation becomes:

$$\ln HDI(t) = \beta_0 + \beta_1 \ln K_{(t)} + \beta_2 \ln TAI_{(t)}$$

β_0 is a constant and β_1 and β_2 are the coefficient of capital and technological progress respectively.

4.2. Data Sources and Estimation Method

The time series data and sources used for estimation of the TAI and HDI from 1995 to 2015 have already been described in sections 2 and 3, while the data for the Gross Capital Formation (GCF) has been retrieved from the World Bank Database. Yearly data for the period ranging from 1995-2015 for eight selected East and South Asian countries have been analyzed via simple econometric techniques. EViews 6 has been utilized to estimate the above mentioned models. After formal stationarity testing of the variables, Panel Cointegration is applied to estimate the short- and long-run relationships between technology progress and economic development. Random Effect (RE) and Fixed Effect (FE) have been applied to estimate the influence of technological progress on economic development. To seek the causal relation between variables on each other, the Granger Causality test has also been performed.

4.3. Empirical Estimation

4.3.1. Stationarity Testing

The most important step of such studies whether data is stationary or non-stationary. Stationarity of the variables have been checked by a Panel root test (based on four tests) and a Hadri test. The results of the Panel Unit root test are presented in Table 13.

TABLE 13. Panel Unit Root Test

Variables	HDI			LNK			TAI		
Method	Stat†	Prob.*	Decision	Stat†	Prob.*	Decision	Stat†	Prob.*	Decision
At Level									
Null: Unit root (assumes common unit root process)									
Levin, Lin & Chu t*	0.980	0.836	Accept	-2.882	0.002	Reject	-4.018	0.000	Reject
Null: Unit root (assumes individual unit root process)									
Im, Pesaran and Shin W-stat	2.866	0.997	Accept	1.659	0.951	Accept	0.1907	0.575	Accept
ADF - Fisher Chi-square	174.367	0.904	Accept	168.175	0.821	Accept	209.791	0.303	Accept
PP - Fisher Chi-square	465.053	0.000	Accept	212.676	0.087	Accept	252.825	0.006	Accept
Null Hypothesis: Stationarity									
Hadri Z-stat	21.840	0.000	Reject	23.292	0.000	Reject	19.016	0.000	Reject
Heteroscedastic Consistent Z-stat	15.011	0.000	Reject	22.902	0.000	Reject	14.458	0.000	Reject
Final Decision	Non-stationary			Non-stationary			Non-stationary		
At first difference									
Null: Unit root (assumes common unit root process)									

Levin, Lin & Chu t*	-8.119	0.000	Reject	-15.327	0.000	Reject	-7.762	0.0000	Reject
Null: Unit root (assumes individual unit root process)									
Im, Pesaran and Shin W-stat	-13.385	0.000	Reject	-15.538	0.000	Reject	-9.353	0.000	Reject
ADF - Fisher Chi-square	567.712	0.000	Reject	600.309	0.000	Reject	421.081	0.000	Reject
PP - Fisher Chi-square	2416.41	0.000	Reject	885.590	0.000	Reject	1311.99	0.000	Reject
Null Hypothesis: Stationarity									
Hadri Z-stat	12.486	0.000	Reject	-7.442	1.000	Accept	15.022	0.000	Reject
Heteroscedastic Consistent Z-stat	8.296	0.000	Reject	5.478	0.000	Reject	13.754	0.000	Reject
Final Decision	Stationary			Stationary			Stationary		

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.*
† Statistics

The results of all panel root tests clearly indicate that the probability value is greater than 5% significance level (p >.05). We therefore cannot reject the null hypothesis, so, we accept that all the series possess a unit root. This indicates that that all the time series are integrated order (1) and non-stationary. At first difference, however, all the time series are stationary integrated order (0), at a statistically significant level (p<.05).

4.3.2. Panel Cointegration

If time series are integrated order (0) at difference and co-integrated, there may exist a long-run as well as a short-run relationship between variables. To examine the long-run and short-run relations, a panel cointegration test has been used and the results are presented in Table 14.

TABLE 14. Panel Cointegration Test

Pedroni Residual Cointegration Test				
Null Hypothesis: No cointegration		Trend assumption: No deterministic trend		
Alternative hypothesis: common AR coefs. (within-dimension)				
	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	1.122	0.131	1.170	0.121
Panel rho-Statistic	-7.065	0.000	-3.332	0.000
Panel PP-Statistic	-14.754	0.000	-9.168	0.000
Panel ADF-Statistic	-5.342	0.000	-1.188	0.117
Alternative hypothesis: individual AR coefs. (between-dimension)				
Group rho-Statistic	0.1357	0.5540		
Group PP-Statistic	-9.7051	0.0000		
Group ADF-Statistic	0.4413	0.6705		
Kao Residual Cointegration Test				
Null Hypothesis: No cointegration				
Trend assumption: No deterministic trend				
	t-Statistic	Prob.		
ADF	4.053435	0.0000		
Residual variance	0.000308			
HAC variance	0.000146			

We have already proved that data is non-stationary at level and stationary at first difference, which is a precondition of panel cointegration. The results of panel cointegration test are presented in Table 14. There are seven tests and eleven outcomes under the Pedroni residual co-integration test. Significant results were found in four tests out of seven tests. Six out of eleven outcomes confirmed that cointegration exists between variables. The second test, Kao residual co-inegration, also was statistically significant ($p<.05$), confirming that cointegration is present. This means that there is a long-run association among human development and technological achievement.

4.3.3. Random Effect and Fixed Effect

The random effect and fixed effects have been adopted to evaluate the impact of technological achievement on HDI (economic development). The test is performed on three different groups of countries. In the first group all 100 countries are used; for comparative analysis we further divide them into two groups. The second group contains eight selected countries (Australia, Norway, Switzerland, Singapore, Netherlands, Ireland, United States, and Germany) with very high human development, while the third group is eight selected East and South Asian countries[2] (Bangladesh, China, India, Japan, Korea, Malaysia, Pakistan, and Sri Lanka).

TABLE 15. Estimation of Fixed Affect and Random Affect

Group of 100 Countries									
Hausman Test			Fixed Affect				Random Affect		
Chi-Sq. Stat.	Chi-Sq. d.f.	Prob.	Variables	LNK	TAI	C	LNK	TAI	C
166.823	2.000	0.000	Coefficient	0.005	**0.132**	0.539	0.005	0.157	0.526
Null: Random is most appropriate Alter: Fixed is most appropriate			Std. Error	0.001	0.014	0.009	0.001	0.014	0.014
			t-Statistic	5.304	9.484	62.940	5.888	11.473	38.504
			Prob.	0.000	0.000	0.000	0.000	0.000	0.000
Group of Eight Selected Very High Human Development Countries									
15.750	2.000	0.000	Coefficient	0.099	0.092	-0.308	0.080	0.079	-0.079
Null: Random is most appropriate Alter: Fixed is most appropriate			Std. Error	0.011	0.027	0.129	0.010	0.027	0.116
			t-Statistic	8.802	3.424	-2.387	7.873	2.979	-0.686
			Prob.	0.000	0.001	0.018	0.000	0.003	0.494
Group of Eight Selected South East Asian Countries									
58.284	2.000	0.000	Coefficient	0.057	0.135	-0.134	0.050	0.216	-0.084
Null: Random is most appropriate Alter: Fixed is most appropriate			Std. Error	0.010	0.039	0.108	0.010	0.037	0.102
			t-Statistic	5.464	3.473	-1.243	5.157	5.878	-0.827
			Prob.	0.000	0.001	0.216	0.000	0.000	0.410

[2] Countries were almost with similar situations in same year in the 1950s. After six decades, many East Asian countries that were behind South Asian countries in the 60's (as per GDP Capita) have overtaken South Asian countries in the last three decades. In spite of similar situation, why South Asian countries legs behind and what are the reasons behind that are needed to explore. That is why I have selected these groups of the countries for current study.

In a panel model, the individual effect term can be regarded as either random or fixed. If the individual effects are correlated with the other regressors, then the fixed effect model is the best fit for the data. On the other hand, if the individual effects are not correlated with the other regressors in the model, the random effect model is most efficient. The Hausman test is used to determine whether a fixed effect or random effect model best fits panel data. The result indicated that the fixed affect is most appropriate. The results of this analysis are presented in Table 15.

The impact of technological progress (TAI) on human development (HDI) is statistically significant. This indicates the one percent increase in technological progress had a meaningful effect on the resulting change in HDI of 13.2% , 9.2%, and 13.5% in the group of all 100 countries, highly developed countries and South East Asian countries respectively. Interestingly, the impact of technological achievement on human development was 4.3% higher in the selected South East Asian countries compared to the selected eight highly developed OECD countries. The results of study endorse all economic and social theories that speak that chance of growth in developing countries is higher than the developed countries, conceivably, the developed countries has reached at saturation point all aspect of development. The developing countries may gain more by investing little on education, heath, and R&D.

4.3.4. Granger Causality

Granger argued that the presence of a cointegrating vector indicates that Granger causality must exists in at least one direction. A variable Granger causes the other variables if it helps forecast its future values. The results of the Pairwise Granger Causality test are reported in Table 16. As our focus is to find the casual relation between technological achievement and human development, we limit our discussion to the relationship between the TAI and the HDI. The results indicate that P value is less than 5% significance level so we may reject the null hypothesis and accept alternative. It means that TAI granger causes HDI as well as HDI granger causes TAI. It indicates that bidirectional causality between human development and technological achievement is present.

TABLE 16. Pairwise Granger Causality Test

Null Hypothesis:	Obs	F-Statistic	Prob.
LNK does not Granger Cause HDI	1900	74.803	0.000
HDI does not Granger Cause LNK		2.153	0.116
TAI does not Granger Cause HDI	1900	4.293	0.014
HDI does not Granger Cause TAI		10.554	0.000
TAI does not Granger Cause LNK	1900	0.180	0.836
LNK does not Granger Cause TAI		2.290	0.102

4.3.5. Discussion of Results

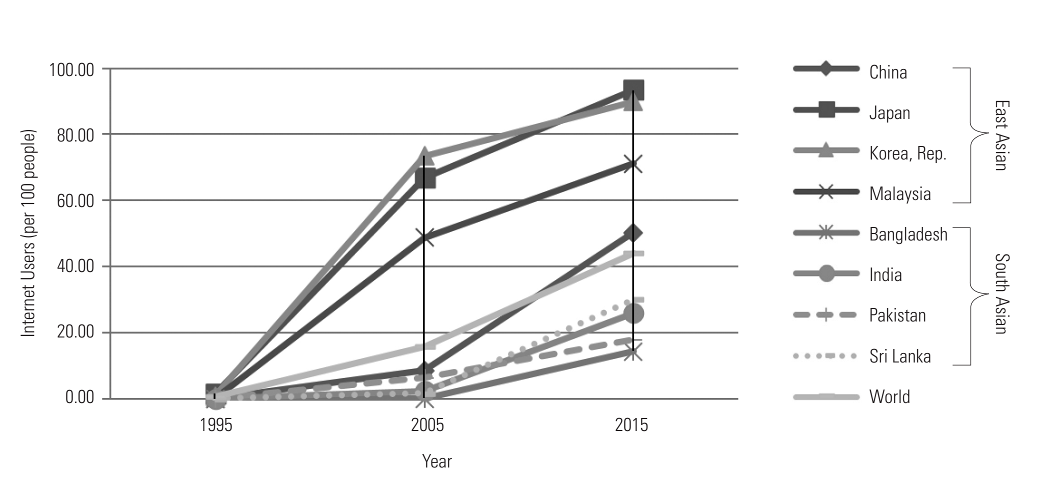
On the basis of our empirical results, we may state that technology progress and achievement are directly and significantly associated with human development in the long run as well as in the short run. One percent increase in country's technological level has been shown to bring about a 13.2%

raise in the country's economic development. It has been observed that the impact of technological progress is 13.5% on human development in South East Asian countries, while it is 9.2% in countries with levels of human development that are 4.3% higher. It has also been shown through empirical testing that there is a bidirectional causal relationship between human development and technological achievement. It indicates that human development cannot be achieved without technology progress, and technology achievement can not proceed without human development. In this economic model, we use the TAI as a policy variables to provide a guideline to the policy makers, planners, and researchers.

5. EAST AND SOUTH ASIAN COUNTRIES (ESACs)

Eight East and South Asian countries (ESACs) we have selected for this paper include four from East Asia (China, Japan, Korea, and Malaysia[3]) and four from South Asia (Bangladesh, India, Pakistan, and Sri Lanka). Although these eight countries have almost similar geographical conditions, there is a huge gap in the economic development of East and South Asian countries. Some of the world's most populous countries, like China (1st), India (2nd), Pakistan (6th), Bangladesh (8th) and Japan (11th) are also included in our eight selected countries. 44.38% people of the total world population are living in these selected eight countries, making the East and South region the most populous region of the world. More than a quarter of the world's gross domestic product, or GDP (26.57% in 2015), is contributed by these eight countries.

FIGURE 6. Internet Users (per 100 people)

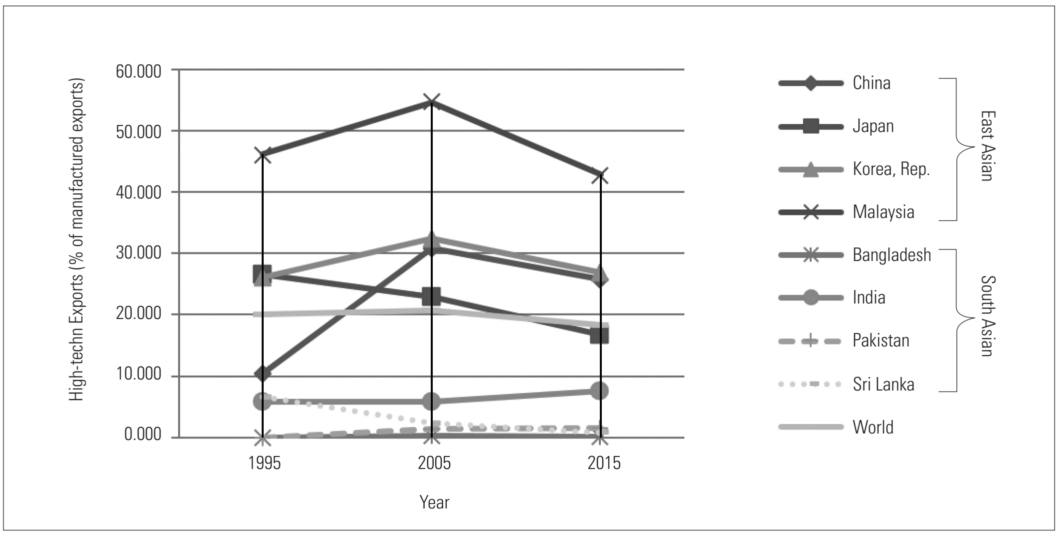


[3] Malaysia is a vibrant economy and considered as an Asian tiger, it is ahead of other South Asia countries in terms of economic, social, and S&T indicators. However, the country is closer and similar to East Asian Countries in regard of S&T development. Accordingly, this study places Malaysia in the group of East Asian countries for comparative purpose, although, Malaysia is the part of South-East Asian region.

The average electricity consumption (kWh per capita) in 2015 for four South Asian Countries (SACs) was 571.92, which is 13 times less than the average consumption of four East Asian Countries (EACs) (7614.40) as shown in Table 17. It is expensive for South Asian countries to provide this basic utility for their people. Similarly, the average fixed telephone plus mobile cellular subscription cost (per 100 people) is 154.75 and 86.21 in EACs and SACs respectively. Use of this old technology in EACs is almost two times higher than in SACs. The state of Internet use in ESACs is presented in Figure 6 and Table 17. It can be seen in Figure 6 that all eight ESACs had the same position in 1995, but the gap between EACs and SACs is increasing year by year.

EACs have overtaken SACs rapidly in the last two decades (Figure 6). Korea Republic (90) Japan (93) and Malaysia are the leaders (figures indicate the percentage of people who are Internet users), while Bangladesh (14), Pakistan (18) and India (26) trail behind. The average percentage of high-technology exports (as a percentage of all manufactured exports) of SACs, at 2.5% are less than 11 times of the average of high-technology of EACs, at 28.04 percent (Figure 7).

FIGURE 7. High-technology Exports (% of manufactured exports)



The gap in exporting high technologies among ESACs can be seen in Figure 7. Malaysia is the leading country of ESACs while the total high tech export of SACs (10.00) is far less than individual countries of East Asia.

Table 17 presents scientific capacity indicators for selected South East Asian Countries. The average total number of publications of EACs (155,640) is 4.5 times higher than those of SACs (34,608). China (24,496) was behind Japan (79,157) in 1995, but in the past two decades, China had a dramatic increase in the number of scientific publications, propelling them to the top (416,409) and leaving Japan far behind with 109,305 in 2015. In terms of changes in the increase in the total number of publications, Malaysia and Pakistan show very good performance; Malaysia is at the top of the selected eight countries with 97%, while Pakistan is on the top in South Asian countries with 93%.

The performance of SACs on human skill development indicators is also dismal as compared to EACs. When looking at occupations using FTE or full-time equivalents, the average number of researchers per million inhabitants of the South Asian countries (158.7) was 25 times less than that of East Asian countries (4028.31) in 2015. In fact the number of researchers of 3 SACs (excluding Bangladesh) in 2015 was only 476.62 per million, which is far less than that of a single country of East Asia like Japan (5187), Korea (7250), Malaysia (2465.25), or China (1211) (Table 17). There is also a huge difference between EACs and SACs in human skill development. The average gross enrolment ratio (GER) (primary to tertiary, both sexes) of SACs countries is 70% which is far behind the average GER of EACs (95%). Similarly, the average percentage of students in tertiary education enrolled in Science, Engineering, Manufacturing and Construction of SACs was approximately 24% in 2015, far less than the average percentage of students (37%) in EACs (Table 17).

TABLE 17. Scientific Capacity Indicators for Selected South East Asian Countries

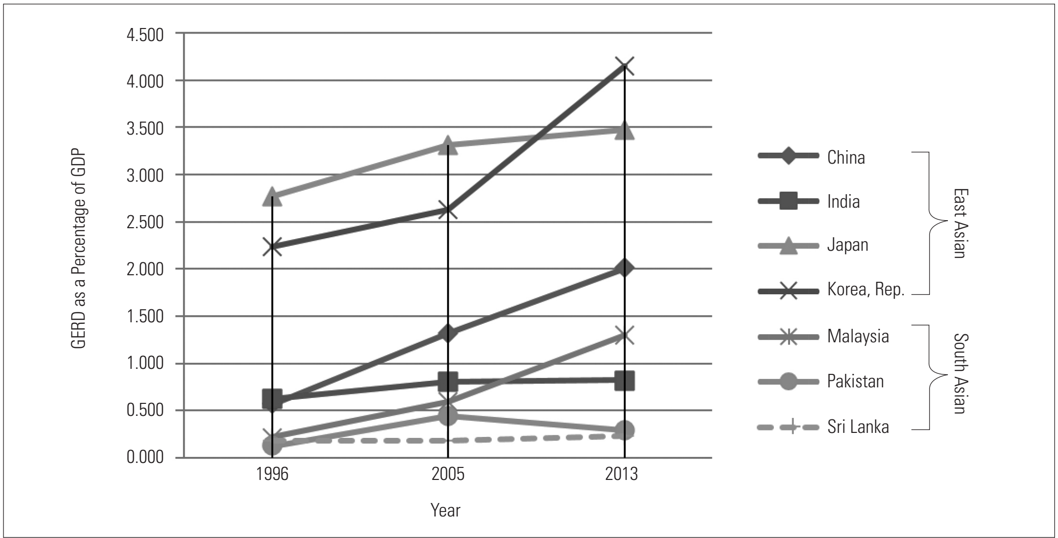
Country		Total No. of Publication†		Percentage of Students in Tertiary Education Enrolled in Science*¥		GER Primary to Tertiary, Both Sexes (%)¥		Researchers per Million Inhabitants (FTE) ¥		Electric Power Consumption (kWh per Capita) €		Fixed Telephone + Mobile Cellular Subscriptions (per 100 People) €	
		1995	2015	1995	2013	1995	2015	1995	2015	1995	2015	1995	2015
East Asia	China	24496	416409	–	–	24.38	90.90	468.50	1211.00	770.18	4326.95	3.58	110.17
	Japan	79157	109305	0.00	33.24	49.77	92.74	4822.50	5187.00	7364.89	7500.15	59.45	170.32
	Korea	7504	73433	21.54e	17.83	85.42	92.00	2253.00	7250.00	3881.02	11717.44	45.33	175.09
	Malaysia	828	23414	17.51e	35.16	45.07	103.36	42.75	2465.25	1981.58	4898.07	20.93	163.44
South Asian	Bangladesh	493	3011	49.74e	34.08	25.98	43.13	–	–	76.08	333.76	0.24	76.61
	India	19688	123206	–	16.60e	4.39	62.66	162.50	179.00	359.90	884.52	1.26	76.61
	Pakistan	781	10962	–	–	114.14	72.39	75.50	175.25	358.60	450.77	1.71	75.98
	Sri Lanka	177	1255	–	20.18	39.02	101.32	201.25	122.37	217.03	618.63	1.40	115.65

*Source:†SCOPUS Data: € WDI, World Bank: ¥UIS Data, UNESCO: *Science, Engineering, Manufacturing and Construction: 'e'=estimated value, 'a'=1997, 'b'=2011, 'c'=2012*

There is consensus among governments, researchers, and economists that investment in research and development (R&D) supports technological progress and as a result raises productivity and generates economic growth. Thus, R&D has a spillover effect on economic growth. This is true at micro and macro levels, for individual companies as well as for national economies. Thus the continued wealth and welfare of modern society depends fundamentally on continuing investment in and leveraging of new knowledge.

Figure 8 reflects the levels of R&D investment in ESACs. The average R&D expenditure, (expressed as a percentage of the GDP) of three SACs (0.44) was six times less than the average R&D expenditure of EACs (2.73) in 2013 (Figure 8). The total R&D expenditure of three SACs, excluding Bangladesh (1.349), is less than the single country of Korea at 4.15 (Table 17). In 1995, Korea (2.24) was behind Japan (2.77) in investing on R&D. Korea has been continuously increasing its R&D budget since 1996 and during the last decade, Korea (4.15) has reached the top position among eight ESACs. The R&D spending of India was 0.63 and is now 0.82, while China was at 0.57 and has now reached 2.01 India and china are five times and two times behind than Korea in context of R&D spending. (Figure 8).

FIGURE 8. Research and Development Expenditure (% of GDP) in ESACs



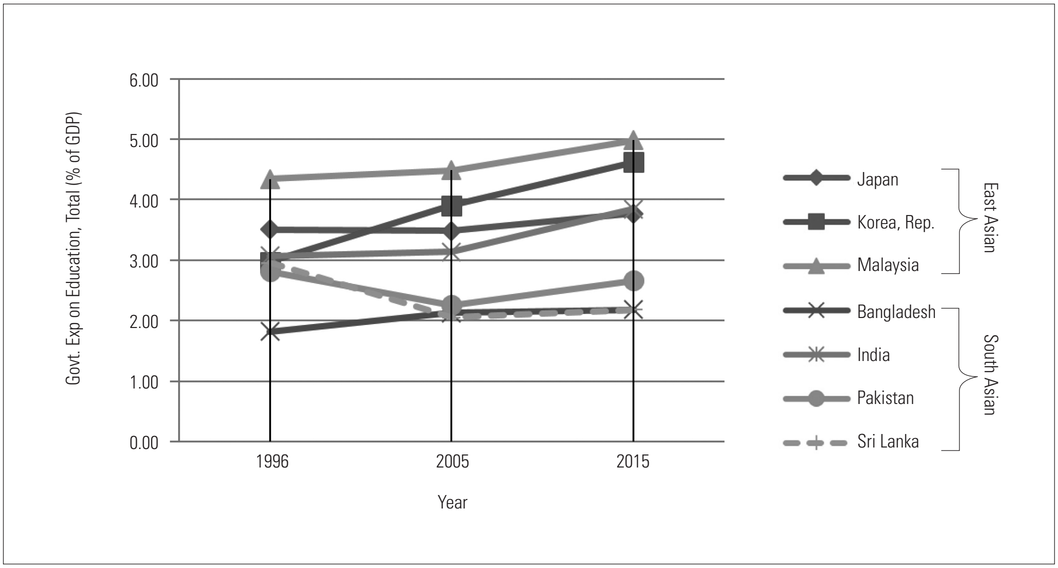
The comparison of spending on education and health are shown in Table 21. The statistics clearly indicate that all ESACs have increased their health and education expenditures since 1995. However, there are huge variations between EACs and SACs in spending on education and health.

TABLE 18. Comparison of Expenditure on Education Health

Country		Government Expenditure on Education, Total (% of GDP)		Health Expenditure, Total (% of GDP)	
		1996	2015	1995	2015
East Asia	China	1.848	-	3.525	5.548
	Japan	3.506	3.771c	6.623	10.229
	Korea, Rep.	2.974	4.618a	3.673	7.373
	Malaysia	4.343	4.980d	2.964	4.169
South Asian	Bangladesh	1.821	2.179d	3.222	2.819
	India	3.066	3.841b	4.019	4.685
	Pakistan	2.817	2.661d	2.504	2.614
	Sri Lanka	2.958	2.182d	3.440e	3.503

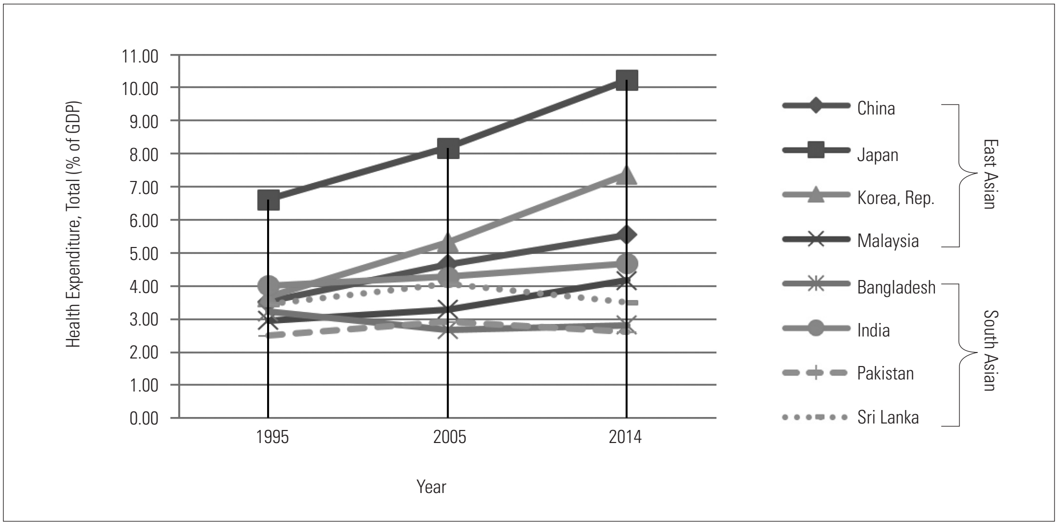
a=2012, b=2013, c=2014, d=2015, - = Data is not available
Source: WDI, World Bank

FIGURE 9. Government Expenditure on Education (% of GDP)



Education is considered the key component to raise the level of human and economic development as well as to facilitate technological progress. Figure 9 shows the spending behaviour of seven ES-ACs (excluding China due to unavailable data) on education. There is a huge gap between Malaysia and the other countries; Malaysia has been increasing its spending on education continuously since 1995 (4.34), with a level of (4.98) in 2015 .While following Malaysia, Korea is also spending more on education and ranks second among ESACs with 4.61 in 2012 (Table 18).

FIGURE 10. Health Expenditure (% of GDP)



In 1995, Korea (2.97), Pakistan (2.81), India (3.06), Sri Lanka (2.95) were roughly equal. Both Korea and India continuously increased their budget for education and reached 4.61 and 3.84 percent of their GDP respectively, while Pakistan and Sri Lanka did not and arrived at 2.66 and 2.18 respectively (Figure 9 & Table 18). The health expenditure of ESACs is shown in Figure 10 and Table 18. A huge gap can be observed between Japan, Korea and the rest of the ESACs. The average expenditure on health of EACs (6.83) was two times higher than SACs (3.60) in 2015. Japan invests the greatest proportion of their GDP on health. Although trends can be seen in all ESAC countries, the increase in Japan and Korea is rapid while other countries, such as Pakistan have seen little movement from their 1995 position in 2015.

5.1. Brief Overview of ESACs in terms of TAI and HDI

If we analyse ESACs in terms of the TAI, it is revealed that the state of EACs is very impressive while the position of SACs is generally not satisfactory. China shows a very strong performance in improving its ranking and TAI value. China is increasing its budget of education, health and R&D continuously and performing very well in all four dimensions of TAI. In 1995, China was at the 78th position; in 21 years since China has secured its position in the top ten technologically advanced countries was in the 9th position in 2015. The second best ESACs performer is Korea, who was ranked the 17th in 1995. After 2005 it rose to the 3rd position along with Japan and United States. Japan has successfully retained its 2nd place position throughout the 21 years from 1995 to 2015. Malaysia is also showing good performance, rising to the 6th position in 2015 from the 12th position in 1995. All four EACs are placed in the “leader” category according to the 2015 rankings (Table 1).

In comparison, the situation of SACs in terms of TAI is very disappointing. India and Sri Lanka are included in the category of dynamic adopters, holding the 75th and 79th positions in 2015. Pakistan and Bangladesh are in the category of marginalized countries; between the 1995 and 2015 rankings Pakistan dropped 24 points from the 67th to 91st while Bangladesh rose two points from 96th to 94th.

In case of HDI, a lot of variations have been seen in ESACs. Here, Korea and Japan are leading; Korea improved 18 points in its HDI ranking raising it from the 30th place (1995) to the 12th (2015) and placing it in the very high human development category. Although Japan dropped 9 points in its HDI ranking, it successfully secured its place in very high human development category. Malaysia and China are in the 58th and 68th position respectively, and are placed in medium human development category. SACs not only lags behind in scientific and technological development but is also weak in human development. No good performance has been observed in any of four SACs. Sri Lanka and India stand at the 85th and 87th position, with only one point improvement in their HDI ranking during 21 years. Bangladesh rose two points while Pakistan shows no change in its HDI ranking and are ranked at 88th and 89th position. All four SACs are in the low human development category (Table 10).

5.1.1. Sub Dimensional Indices of TAI

Sub-dimensional indices of TAI are presented in Table 19. China, Japan, and Korea are leading the Technology Creation Index (TCI) while the other ESACs are far behind. The primary reason is that the number of patents granted to residents per million in Bangladesh (21), Sri Lanka (71) Pakistan (172), Malaysia (344) and India (720) are very low compared to Korea (97294), China (162680), and Japan (177750) (Table 23). Malaysia is on top in the Diffusion of Recent Innovation Index (DRII). The value of high-technology export (% of manufactured exports) of Malaysia (43.57) is very high while the other ESACs, including Bangladesh (0.17), Sri Lanka (0.99), Pakistan (1.88), India (8.07), Japan (16.78), China (26.97) and Korea (27.10) have low values (Table 19).

TABLE 19. Sub-Dimensions Indices of TAI

	Technology Creation Index (TCI)			Diffusion of Recent Innovation Index (DRII)			Diffusion of Old Innovation Index (DOII)			Human Skill Development Index (HSDI)			TAI		
Country \ Year	1995	2005	2015	1995	2005	2015	1995	2005	2015	1995	2005	2015	1995	2005	2015
China	0.008	0.094	0.504	0.097	0.266	0.480	0.511	0.678	0.558	0.101	0.248	0.229	0.179	0.321	0.443
Japan	0.500	0.619	0.501	0.302	0.547	0.614	0.882	0.870	0.685	0.417	0.545	0.327	0.525	0.645	0.532
Korea, Rep.	0.039	0.254	0.291	0.270	0.652	0.639	0.815	0.874	0.721	0.530	0.727	0.445	0.414	0.627	0.524
Malaysia	0.000	0.000	0.001	0.431	0.665	0.705	0.710	0.763	0.649	0.669	0.617	0.462	0.453	0.511	0.454
Bangladesh	0.000	0.000	0.000	0.000	0.002	0.038	0.144	0.291	0.298	0.108	0.234	0.207	0.063	0.132	0.136
India	0.011	0.008	0.005	0.055	0.053	0.158	0.379	0.424	0.342	0.016	0.155	0.530	0.115	0.160	0.259
Pakistan	0.001	0.000	0.001	0.000	0.045	0.075	0.401	0.414	0.305	0.484	0.209	0.182	0.222	0.167	0.141
Sri Lanka	0.000	0.000	0.000	0.015	0.025	0.142	0.350	0.475	0.411	0.163	0.361	0.388	0.132	0.215	0.235

TABLE 20. Data for Indicators of TAI

Country	Total Patent Grants to Resident	Charges for the Use of Intellectual Property, Receipts (BoP, Current US$)	Internet Users (per 100 People)	High-Technology Exports (% of Manufactured Rxports)	Fixed Telephone + Mobile Cellular Subscriptions (per 100 People)	Electric Power Consumption (kWh per Capita)	GER Primary to Tertiary, Both Sexes (%)	Percentage of Students in Tertiary Education Enrolled in Science
Bangladesh	21 a	902006.17 a	9.60 a	0.17 c	76.61 a	278.60 c	31.81 b	16.63 d
China	162680 a	886670295.00 b	49.30 a	26.97 b	110.17 a	3475.01 c	-	-
India	720 a	658722433.00 a	18.00 a	8.07 b	76.61 a	743.74 c	55.40 d	33.24 b
Japan	177750 a	36832562676.00 a	90.58 a	16.78 b	170.3 a	7752.49 c	89.93 b	17.83 b
Korea Rep.	97294 a	5150900000.00 b	84.33 a	27.10 b	175.09 a	10345.60 c	91.64 a	35.16 a
Malaysia	344 a	4328100000.00	67.50 a	43.57 b	163.44 a	4345.47 c	94.35 b	34.08 b
Pakistan	172 a	12000000.00 a	13.80 a	1.88 b	75.98 a	451.70 c	70.24 a	-
Sri Lanka	71 b	..	25.80 a	0.99 b	115.65 a	526.81 c	94.99 b	19.90 a

a= 2014, b=2013, c=2012, d=2011, - = data not available
Source: World Bank, UIS, WIPO

Korea is on the top in both indices, Diffusion of Old Innovation Index (DOII) and Human Skill Development Index (HSDI) among ESACs. Electricity is the basic necessity of life as well as it is key factor for industrial progress. Electric power consumption (kWh per capita) of Korea (10345.60) is high relative to other ESACs, including Bangladesh (278), Pakistan (451.71), Sri Lanka (526.18) and India (743.74), China (3475.01), Malaysia (4345.47) and Japan (7752.49) (Table 20). Korea (35.16) is on the top in enrolment in science at the tertiary level, an important indicator of skill development ability.

5.1.2. Sub-Dimensional Indices of HDI

Sub-dimensional indices of the HDI are presented in Table 21. Japan is on the top of the ESACs followed by Korea (0.95) for the Health Index (HI) in 2015. Both Japan and Korea have a high life expectancy (83.6 and 82.6) compared to Bangladesh (61.9), Pakistan (61.5), India (68.0), China (73.8), Malaysia (74.7) or Sri Lanka (74.8) (Table 22). The situation is reversed with regards to the Education Index (EI), with Korea (0.803) leading among the ESACs and followed by Japan (Table 21).

TABLE 21.Sub-Dimensional Indices of HDI

	Health Index(HI)			Education Index(EI)			Income Index(II)			HDI		
Country	1995	2005	2015	1995	2005	2015	1995	2005	2015	1995	2005	2015
Bangladesh	0.455	0.592	0.623	0.204	0.211	0.256	0.414	0.260	0.308	0.358	0.354	0.396
China	0.703	0.761	0.746	0.393	0.409	0.463	0.484	0.452	0.570	0.527	0.541	0.593
India	0.411	0.491	0.511	0.255	0.251	0.280	0.456	0.345	0.409	0.374	0.362	0.400
Japan	1.000	1.000	0.993	0.749	0.732	0.726	0.823	0.794	0.756	0.857	0.842	0.825
Korea, Rep.	0.810	0.898	0.949	0.752	0.802	0.803	0.738	0.735	0.750	0.767	0.811	0.834
Malaysia	0.763	0.756	0.711	0.516	0.558	0.492	0.712	0.667	0.685	0.664	0.661	0.629
Pakistan	0.443	0.472	0.450	0.131	0.147	0.133	0.524	0.393	0.384	0.366	0.337	0.323
Sri Lanka	0.688	0.767	0.713	0.632	0.634	0.627	-	-	-	0.440	0.467	0.447

TABLE 22. Data for HDI Indicators

Country Name	Life Expectancy at Birth, Total (years)	Mean Years of Schooling of Adults	Expected Years of Schooling of Children	GNI per Capita, PPP (2011 Constant International $)
Bangladesh	71.6 b	5.1 c	10.8 a	3299.7 a
China	75.8 b	7.5 c	13.4 a	13323.0 a
India	68.0 b	4.4 c	12.3 a	5649.4 a
Japan	83.6 b	11.5 c	15.5 a	35779.3 a
Korea Republic	82.2 b	11.8 c	17.1 a	34677.0 a
Malaysia	74.7 b	9.5 c	12.7 a	24494.2 a
Pakistan	66.2 b	4.7 c	8.0 a	4962.8 a
Sri Lanka	74.8 b	10.8 c	13.7 a	-

a= 2015, b=2014, c=2013, - = data not available: Source: World Bank, UIS, WIPO

The performance of Korea in both indicators of education is very good. The average number of years of schooling and expected years of schooling for Korea are 1.8 and 17.1 respectively, which is very high relative to the other ESA countries under study. In terms of an income index, Japan and Korea is in first and second position respectively among ESACs. The GNI per capita of Japan is 35779.3 which is 10.8, 7.2, 6.3, 2.6 and 1.4 times higher than Bangladesh, Pakistan, India, China and Malaysia respectively (Table 22).

6. CONCLUSIONS

On the basis of the TAI values and facts and figures presented in this study, it can be concluded that most of South Asian countries (SACs) are not only far behind scientifically and technologically but are also weak in human development. If we take a bird's eye view on the history of these selected eight East and South Asian countries (ESACs), we have found that they started their journey in similar conditions. In contrast, East Asian countries (EACs) seem to be very developed scientifically, technologically and economically. The TAI results show that the East Asian countries under study have an index value above 0.425 hence are in the leader category, two South Asian countries (India and Sri Lanka) are in the dynamic adopter category and other two (Pakistan and Bangladesh) are classified as marginalized countries. South Asian countries have a long voyage of technological development to catch up. However, East Asian countries are still behind some OECD countries in terms of human development. They also have to work hard to pass the level of economic development found in OECD and European countries. The results of TAI also indicate that the level of technological progress, readiness, and preparedness to contribute in the global knowledge-based economy of the majority of South Asian countries is very low. That is why the gap between South Asian and East Asian countries and other developed countries is expanding with the passage of time.

In terms of HDI, only two countries (Korea and Japan) among ESACs under study have succeeded to secure rankings of very high human development. Malaysia and China are still behind, placing in the medium human development category, while all SACs are very weak in human development and are in the low human development category. It follows that the counties which are weak technologically are also incapacitated in human development.

To find the nexus between technological achievement and economic development empirically, econometric techniques including panel cointegration, fixed effect, and granger causality have been performed. It has been confirmed empirically that long-run as well as short-run associations exist between technological progress and economic development. The results of a fixed effect analysis show that the impact of technological achievement (TAI) on economic development (HDI) is 13.2% at a 5% significance level. This indicates that a one percent increase in technology progress (TAI) will lead to a 13.2% enhancement in economic development (HDI). Further, it has been observed that the impact of technological progress on economic development is 4.3% higher in the eight selected East South Asian Countries (13.5%) compared to eight selected highly developed countries (9.2%). The results of our study endorse this notion that the chance of growth in developing countries is higher than developed countries, and they may be able to achieve more by investing less. The Granger casualty test results endorse a causal bidirectional relationship between economic development and technological progress, indicating that human development cannot be achieved without technological progress, and technological achievement may not possible without human development; each is compulsory for the other. In this economic model, we use the TAI as policy variables that provide the guidelines to policy makers, planners and researchers.

6.1. Policy implications

This study provides valuable and significant information to the policy makers and planners of ESACs to formulate science, technology and innovation policies. The results can help them decide where to take the first step in the long voyage of building adequate scientific and technological capabilities fitted to the socio-economic requirements of their people. The TAI results clearly indicate that only EACs are advanced enough to place in the leader category, while SACs are placed in the categories of dynamic adopter and marginalized countries. It is plain that ESACs, especially SACs, require the capability to manage and adapt new technologies for their local needs. To adopt and disseminate both established and innovative technologies, ability and knowledge are required but the lag in scientific & technical knowledge and human skill make conditions in these countries unfavorable. SACs are not only far behind in science, technology and innovation but also in economic and human development. Although SACs are enriched with natural resources, they are unable to fully utilize these to the benefit of the public owing to these deficiencies in capacity.

SACs under study are lagging behind in old inventions and utilities, such as telecommunications and electricity, and completely unable to adopt recent high tech innovations. Large portions of rural areas are still deprived of basic technologies and utilities (telephones and electricity) which are structural and functional units of technological progress that serve as prerequisites to the new advanced technologies and innovation driving progress in the 21stcentury. Technology simply cannot be spread and the capacity to innovate cannot be attained without the vital presence of energy infrastructure (gas and electrical power). It is a mistake to assume that by applying external knowledge and equipment, the technology can be easily transferred, diffused, and adopted. Actually, to adopt and implement new technology in a country, a minimum level of infrastructure and capacity is required. Therefore, SACs have to improve their capacity building to be able to consume foreign technologies and integrate them into their countries. This will enable them to create and develop new technologies to fulfil their local requirements.

Momentous action is needed to accelerate the technological progress in SACs. Improvement in human skills, in particular, is vital to boost technological competency. Although Japan and Korea perform well in the gross enrolment ratio, they have yet to achieve a 100% literacy rate. The gross enrolment ratio of students in science at the tertiary level is not very good in ESACs, except in Korea and Japan. The question that arises is, is the education system of the ESACs satisfactory to encounter the challenges of the twenty-first century? Unfortunately, the answer at this time is no.

To achieve the needed improvements in their citizens' human skill level, ESACs must increase their educational and R&D expenditure. The results of TAI also indicate that the technological readiness and preparedness to participate in the global knowledge-based economy of SACs countries is very low compared to EACs. This is why the gap between SACs and EACs countries is increasing with passage of time. Thirdly, there is a large gap within EACs and SACs countries for the indicators examined in this study. For instance, in terms of publications, India (123206), Japan (109305), Korea (73433), Malaysia (23414), Pakistan (10962), Bangladesh (3011) and Sri Lanka (1255) are about 3, 4,6, 18,38,138, and 332 times less respectively than China (416409) in 2015 (Table 17). Malaysia spends 4.98 per cent of GDP on education which is two times higher than Pakistan which spends only 2.66 per cent of GDP on education in 2015 (Table 18). Sri Lanka spends 0.23 per cent of GDP on R&D which is seventeen times less than 4.15 per cent of GDP of Korea in 2013 (Figure 8).

This failure and worsening condition of SACs is the result of lack of support from political leaders and the failure of existing policies to solidify the importance of the components of the engine for economic growth and development: Education, research & development, science, technology and innovation. The efforts made by SACs in the fields of education, science, technology and innovation are not adequate to meet their needs. Therefore, it is critical for ESACs to realize the importance and significance of education, research & development and science, technology and innovation and their impact on economic growth, human and industrial development. They can follow the model of rising economies like Korea, Singapore, Hong Kong and Taiwan who have been spending a high percentage of their budget on the basic facilities of twenty-first century global life, applied research, health and education. In the long run, ESACs and especially SACs have to invest more in a number of areas. These include the energy sector (to increase capacity for power and gas), education, research & development (to obtain the spill over effect of investments on invention), technology creation (in the form of high-tech export, patents, and royalties) and human development. The direct and indirect implications of the study have been summarized in point form as follows:

Direct Implications:

i. High investment into the energy sector to provide basic necessities of life (electricity, gas) to the public
ii. Augmented education budget (for primary as well as higher levels)
iii. Supporting research and development by increasing the R&D budget
iv. Promote information and communication technology (ICT)
v. Massive investments on the basic needs of the public to establish health care, water treatment facilities, roads and infrastructure, and so on
vi. Need to promote high-tech imports by relaxing excise rates, tariffs, duties, and quotas

Indirect Implications:

i. Need for a vision of the future assessment (identifying what the priority areas in STI are)
ii. Quality enhancement (design and launch programme standards which ensure quality services according to local needs)
iii. Creating a leadership and management development system in university level; people

from institutions who have executive responsibilities and decision-making powers of considerable scope must have leadership as well as managerial and administrative qualities

iv. Refining and promoting teaching excellence to facilitate skill development; a program for the scholarship of teaching and learning for teachers and professors should be launched by the government
v. Bridging the links between research & development and practice (to create up-to-date research environments at universities R&D organizations)
vi. Taking initial steps to support the synthesis of existing knowledge and to build and expand the national knowledge base
vii. Improve educational tools and materials (revise curriculum and syllabi at primary and college level in accordance with best practices)

6.2. Limitations of Study

One of the problems faced in the current study, which is common to all statistical studies, was related to the availability of reliable data. The index of indicators is incomplete in its coverage of countries, limited in coverage to 100 out of the 196 countries of the world. We attempted to obtain data for all eight sub-indicators for each country, relying upon the statistical publications and databases of major international organizations. Missing values have been estimated by liner interpolation and forecasting where required, but we were forced to use zero for TAI and HDI values where data of the country is not available.

6.3. Future Outlook

Finally, the TAI appears to be a reasonable composite S&T indicator for assessing the technological readiness of a nation without concluding anything about its overall S&T capability. As such, it may be useful for detailed studies of regional technical capabilities; for example OECD, OIC, and SAARC nations for being of direct interest, oil-producing countries due to their prominent role in the world economy, and Central Asian republics as a future source of the world's energy supplies.

The indices of the individual dimensions of the TAI and HDI could provide meaningful information and insight about level of technology progress and economic development of developing countries as well as different regions of world. We would suggest a more detailed analysis of these as a subject of future research. For example, the standard deviation of TAI values as a tool for estimating the technological gap of nations appears to be working reasonably well in principle, but would benefit from being revisited in detail.

Ideally, the efforts following from the direct and indirect implications listed above would improve the status of lagging nations and raise them into a more equal stance in the knowledge-based global economy.

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APPENDIX 1. Availability of Data Indicators and Strength of Indicators

Name of Indicator	Number of Countries (Data available)	Number of Countries (Data not available)
Gross enrolment ratio all levels (except pre-primary)	95	5
Gross enrolment ratio in science (Tertiary)	56	44
Receipt of charges for the use of intellectual property	76	24
Patent grants per million inhabitants	82	18
Electric power consumption (kWh/capita)	97	3
Fixed telephone+ Mobile cellular subscriptions (per 100 people)	100	0
Internet users (/1000 people)	100	0
High-technology exports (% of manufactured exports)	95	5

Number of Countries (100)	43	29	18	7	2	1
Strength of Indicators (8)	8	7	6	5	4	3