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Longitudinal and Comparative Perspectives on the Competitiveness of Countries: Learning from Technology and the Telecom Sector

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Abstract

Country competitiveness is gaining importance across the world in the face of complex economic challenges. There is a need to revisit factors of competitiveness and evolve better evaluation methods. The linkage between technological and overall country competitiveness has not been sufficiently explored, particularly in the context of emerging countries. India is one of the leading large emerging countries, and it is trying to improve its overall competitiveness and growth through technology. The purpose of this paper is to present better criteria and indices of overall and technological competitiveness and to develop comparative views of the major countries. The data are compiled from best of competitiveness reports and other sources. Composite indices were developed to promote comparative perspectives. While emerging countries like Brazil, China, and Russia, which share similarities with India, have duly recognized the importance of innovation, technology development, and research and development, India needs to perform a major catch-up on technological competitiveness to sustain its long-term overall competitiveness. The emerging scenarios have rich insights and implications for discerning leadership in industry, governments, and academia. The paper provides longitudinal perspectives and rich, comparative, insightful views for leaders to plan actions to enhance technological and overall competitiveness.

Keywords: Technological competitiveness, country competitiveness, telecom sector, technology management, emerging countries

JEL Classification codes: O14, D24, F23, L96

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Country competitiveness is gaining importance across the world in the face of complex economic challenges and stagnation. Competitiveness is vital to improving and sustaining development, economic prosperity, and quality of life, and it is relevant across levels, from country, industry, supply chain, and firm to products. It has been receiving increasing attention of leadership in industry, government, and academia, even if less explicitly. Competitiveness is a necessity, and nations need to “assume competition” (Hunt, 2000, p. 1); this expression is found in many occasions, from daily life conversations to journals, books, and discussions. For years, there has been concern regarding the competitiveness of countries and their growth (Porter, 1990a, 1990b; Porter & Stern, 2001). The increasingly complex global landscape and economic challenges following the strategic discontinuity of 2008 are demanding new perspectives. Competitiveness improvements at macrolevel, particularly in technological contexts, take time; hence, longitudinal and lasting perspectives are necessary.

While country competitiveness research has developed, the needs related to technological competitiveness in the context of emerging countries are less addressed. Some country competitiveness reports (e.g., World Economic Forum [WEF], 2009; Institute for Management Development [IMD], 2009) were originally more investment driven, which may be in line with the recent globalization drive. These reports attempted to be comprehensive – they have more than 100 criteria – but the specific relevant driving factors in a specific context such as that of emerging countries (e.g., quality human factors, technological capabilities) are not addressed adequately or are lost in overall views. More importantly, there is no adequate research or availability of sector competitiveness indices (overall or technological) to guide policies and strategies or evaluate the impact of decisions and actions. Technological change is often found to be a driving force of productivity growth (Kumar & Charles, 2009) and demands technological capabilities and competitiveness. Addressing this vital need to understand situations, trends, and sources of competitiveness through comparative benchmarking is a key area of research of our team.

The key purpose of this paper is to develop better indices of overall and technological competitiveness and to promote comparative views of the major countries of the world. Business and government leaders tend to talk loosely about competitiveness. Without better indices to define and measure competitiveness, most of the talk fails to be translated into relevant targets, action, review, and follow-up. Our studies of select countries have shown the positive impact of such a directed quantitative approach. For instance, the sustained leadership of Japan in science and technology – in top 3 ranks since the early 1990s – and in technology-based industries (e.g., information and communications technologies) can be partly attributed to such an approach (Momaya, Hayashi, & Tokuda, 2006).

This paper also highlights the overall competitiveness and the technological competitiveness positions of India. Understanding the trends in technological competitiveness is very important for India, which is trying to enhance its contributions to the world output in multiple domains from human resources to manufacturing and emerging knowledge-based industries. There is also a focus on technological competitiveness in the telecom sector, given its strategic and hi-tech nature (Mani, 2005) and unique position: The sector is heavily dependent on the advancement of technology and highly consumer-oriented at the mass scale.

The major contribution of this paper comes from its presentation of several new approaches to evaluate overall and technological competitiveness and linkages. Prior efforts at competitiveness evaluation (Momaya, 2001, 2008) are extended, particularly at industry level. Several useful indices are developed to aid competitiveness leaders' longitudinal decision making. The following sections provide background information about competitiveness, technological competitiveness, and indicators of technological competitiveness before indicating the methodology used for this study and the resulting assessments.

Competitiveness

Competitiveness is a concept focused on the business ability, productivity, and performance of a firm, sector, or nation in a comparative manner. International competitiveness (also referred to as global competitiveness) can be viewed along three key dimensions:

1. Company competitiveness, namely the ability to design, produce, and/or market products superior to those offered by competitors, considering the price and nonprice qualities;
2. Sector competitiveness, namely the extent to which a business sector offers potential for growth and attractive returns on investment; and
3. Country competitiveness, namely the extent to which a national environment is conducive or detrimental to business (D'Cruz & Rugman, 1992).

This paper is focused on industrial competitiveness at the country level (for a conceptual framework linking several levels, see Momaya, 2001). A relevant working definition of country competitiveness, adapted from Momaya (2008), is as follows: the capabilities of a country to nurture industries, or segments, organizations (including institutions), and firms that produce goods and services that meet the needs of domestic and international markets and generate relatively high factor employment and income levels, while citizens earn a standard of living that is both rising and sustainable over the long-run.

At the country level, the pillars of economic competitiveness include institutions, infrastructure, macroeconomic stability, health and primary education, higher education and training, goods market efficiency, labor market efficiency, financial market sophistication, technological readiness, market size, business sophistication, and innovation (WEF, 2009). Although substantial gains can be obtained by improving various pillars of competitiveness, all but one of these factors (viz., technological innovation) eventually run into diminishing returns. In the long run, standards of living can be expanded only through technological innovation. According to Fuller (2006), amid all the high-profile concerns over off-shoring, industry maturation, even terrorism, one anxiety eats away at thoughtful citizens of even developed countries such as the United States of America: the technological competitiveness of the nation.

Technological Competitiveness

Technological competitiveness can be defined as the collective technological capability needed to be competitive, namely for a nation or a company to maintain survival and sustainable growth (Banwet, Momaya, & Shee, 2003). This involves the technological ability to secure market superiority by producing less expensive and higher quality goods and services than those of competing companies or countries or by developing new products. The acquisition and development of technology enhances competitiveness, and firms that are not equipped with sound technology and research and development (R&D) initiatives may not be able to compete in the long run in an open economy; Kumar and Charles (2009) have provided empirical evidence of this phenomenon in the Indian context.

The Institute for Trade and Commercial Diplomacy (ITCD, 2009) explained the following:

> *Technological Competitiveness represents the ability to provide leading-edge technical capabilities, superior performance characteristics, fuel economy, or reliability. Technological competitiveness can sometimes be more important than price competitiveness in international trade, particularly in advanced-technology industries such as telecommunications equipment and aerospace.*

In modern societies, national competitiveness is based primarily on technology: Science and technology constitute the decisive factors in the new productive forces. Developing countries that succeed rely heavily on technology for economic expansion in the belief that science and technology will constitute the core of competitiveness in the future (Porter, Roessner, Jin, & Newman, 2001). Technological capabilities and the level of development are two of the key country determinants explaining inward and outward investment and exports (Narula & Wakelin, 1998).

Indicators of Technological Competitiveness

An extensive literature review of national innovation systems, technological competitiveness and innovation systems in the telecom sector, and indicators of technological competitiveness was undertaken to identify competitiveness factors and indicators. Given the focus of this paper, only the literature on indicators of technological competitiveness is synthesized. Indicators of technological competitiveness are numerous; identifying the more relevant ones for a particular context is, therefore, a challenging task. Multidimensional measures of science which impact on the social, cultural, health, and environmental aspects, among others, also need to be considered.

The Organisation for Economic Co-operation and Development (OECD, 1997) offered the following list of indicators of technological competitiveness:

1. Input: R&D investments by the private sector, R&D tax credits, subsidies, and grants, investment in personnel training and information technology;
2. Process (i.e., flows): technical collaboration among enterprises, joint research activities, copatenting, copublications, personnel mobility, Intellectual Property Rights (IPR) rules, labor market policies,

exchange programs to facilitate collaboration, adaptation of technology after transfer of technology (TOT), new products, patents;

3. Output: technology balance of payment (net exporter or importer of knowhow), embodied technology flows (acquired technologies obtained from imports of capital goods and intermediary products, flow of machinery, equipment, and components that incorporate new technology), diffusion of equipment and technologies as a result of R&D.

According to the International Telecommunication Union (ITU, 2009), the main technological competitiveness indicators in the telecom domain are telecom equipment exports and telecom equipment imports. Another indicator derived from the export and import of the telecom equipment is the Telecom Trade Competitiveness Index (TTCI) (Momaya & Goyal, 2007). The evaluation of competitiveness is done at factor and criteria level (Momaya, 2001), and indicators at the criteria level need to be identified carefully for a particular context. Among many key indicators of a country's technological competitiveness are aggregate personnel employed in R&D, aggregate expenditures on R&D, openness to international trade and investment, strength of protection for intellectual property, share of gross domestic product (GDP) spent on secondary and tertiary education, GDP per capita, percentage of research and development expenditures funded by the private industry, percentage of R&D performed by universities, access to capital, strength of national antitrust policy, R&D spending funded by private sector, the outcome of vigorous rivalry and spending by venture-backed companies, and the number of international patents issued to a country (Porter & Stern, 1999; Roessner, Porter, Newman, & Jin, 2002).

Klienknecht, Montfort, and Brouwer (2002) have highlighted R&D efforts, patents, and patent applications as the traditional innovation indicators and total innovative expenditures, sales of imitative and innovative products, and new product announcements as the new innovation indicators. According to Godin (2006), the relevant indicators for science, technology, and innovation policy are the following:

1. Input: research budget or gross expenditures on research and development (GERD);
2. Output: patents, high-technology products, marketed innovation, number of scientists a nation produces, quantity of output of a scientific or technological type, efficiency, economic growth, productivity, profitability, quality of life. Productivity may be part of the science system itself, or scientific productivity (academic papers), or the contribution of science to economic growth and productivity.

Porter and Stern (2001) suggested that U.S. patents are a most effective indication of innovative intensity, though patterns of exports in the international high-technology markets are also the measure of innovation success. The measures used for common innovation infrastructure are the number of employed scientists and engineers, the overall level of R&D expenditures, the share of GDP devoted to expenditures on higher education, a measure of the effectiveness of intellectual property protection, a measure of the economy's openness to international trade, and R&D tax policies. The measures used for cluster specific innovation environment include the share of national R&D expenditures funded by the private sector to reflect the overall private R&D environment and the relative concentration of patenting activity across technological fields to reflect the degree of technological specialization. The measures used for the quality of linkages include the share of national R&D expenditures performed within the university sector. Linkages also take place through channels that are more difficult to measure, such as venture capital networks, the top institutes, and other informal company networks.

Furman, Porter, and Stern (2002) used the same measures to evaluate the national innovation capacity of 17 OECD countries. Hu and Mathews (2005) carried out the same measurements to determine the national innovative capacity in East Asian countries, Korea, Taiwan, Hong Kong, and Singapore. Hu and Mathews (2008) carried out these measurements to determine the national innovative capacity in China. Concerning the overall competitive system for a nation, Cho and Moon (2005) have suggested a dual double diamond approach and listed a number of variables regarding the factor conditions, business context, related and supporting industries and the demand conditions of a nation with additional scope dimensions such as international-domestic contexts and the source dimension such as physical-human factors.

In terms of constructs, other indicators of technological competitiveness are the national orientation, socioeconomic infrastructure, technological infrastructure, productive capacity, and technological standing (Porter, Jin, Newman, Johnson, & Roessner, 2006). The first four are the input indicators, and technological standing is the output indicator. Some of the variables included in these constructs are the following: the value of high tech exports, royalty/license fees, receipts, the net percentage of students enrolled in secondary education, the gross percentage of students enrolled in tertiary education, foreign direct investment (net inflow, balance of payments), patent applications by nonresidents, electronic data processing equipment purchases, the number of scientists and engineers engaged in research and experimental development, the ratio of royalty and license receipts and payments (balance of payments), connectivity (internet hosts per capita, telephone mainlines per capita, mobile subscribers per capita), patent applications by residents, scientific and technical publishing, research and development expenditures, the value of total electronics production, manufacturing value added, and services value added.

Castellacci (2003) identified the following constructs for innovative performance:

1. The creation of new products and the type of innovative expenditures;
2. The degree of interactions and the so-called *systemicness* of the knowledge base;
3. The imitation of new products and the introduction of new processes;
4. The innovative intensity and the level of technological opportunity.

Balzat and Pyka (2005) classified the variables used to measure the national innovation system: innovative efforts, institutional framework conditions, knowledge base, openness and financial conditions, and sectoral specifics. Innovation and technology development are the result of interactions and relations among the actors in the system, namely enterprises, universities, and government research institutes. The measurement and assessment of national innovation systems has centered on four types of knowledge or information flows:

1. Interactions among enterprises, primarily joint ventures and other technical collaborations;
2. Interactions among enterprises, universities, and public research institutes, including joint research, copatenting, copublications, and more informal linkages;
3. Diffusion of knowledge and technology to enterprises, including industry adoption rates for new technologies and diffusion through purchase of machinery and equipment; and
4. Personnel mobility, focusing on the movement of technical personnel within and between the public and private sectors (OECD, 1997).

Methodology

Different methods have been experimented to develop more effective ways to evaluate competitiveness and patterns among the selected countries. To have a comparative perspective with a fair representation of the world scenario, a set of top 21 countries were selected in terms of GDP and population. The comparative study was divided into two phases of assessment: the overall competitiveness assessment and the technological competitiveness assessment. In each of these phases, the specific aspects of the telecom sector were focused on. For this purpose, extensive secondary data were obtained from carefully selected sources. Care was taken to select only a few relevant indicators rather than identify too many indicators, as is common in competitiveness reports (Momaya, 2011).

In the overall competitiveness assessment phase, the selected countries were grouped in two categories: developed and developing countries. They were then compared in terms of GDP and population. The telecom service industry scenario was then examined through comparing findings for total telephones, teledensity, and 5-year average telephones growth rate. Finally, the overall competitiveness status of these countries was compared with the newly introduced *composite overall competitiveness index* (COCI).

In the technological competitiveness assessment phase, the selected countries were compared in terms of the following indicators: gross domestic expenditure on R&D (GERD) in PPP US$, GERD as percentage of GDP, the newly introduced GERD sourcing index (GSI), number of researchers (full-time equivalent), number of researchers per million inhabitants, the newly introduced researchers' employment index (REI), patent applications by the patent office, residents' patent share in the patent applications by the patent office, patents in force by the patent office, patent applications by country of origin, residents' patent filing per US$ billion GDP, residents' patent filing per million population, and residents' patent filing per US$ million R&D expenditure.

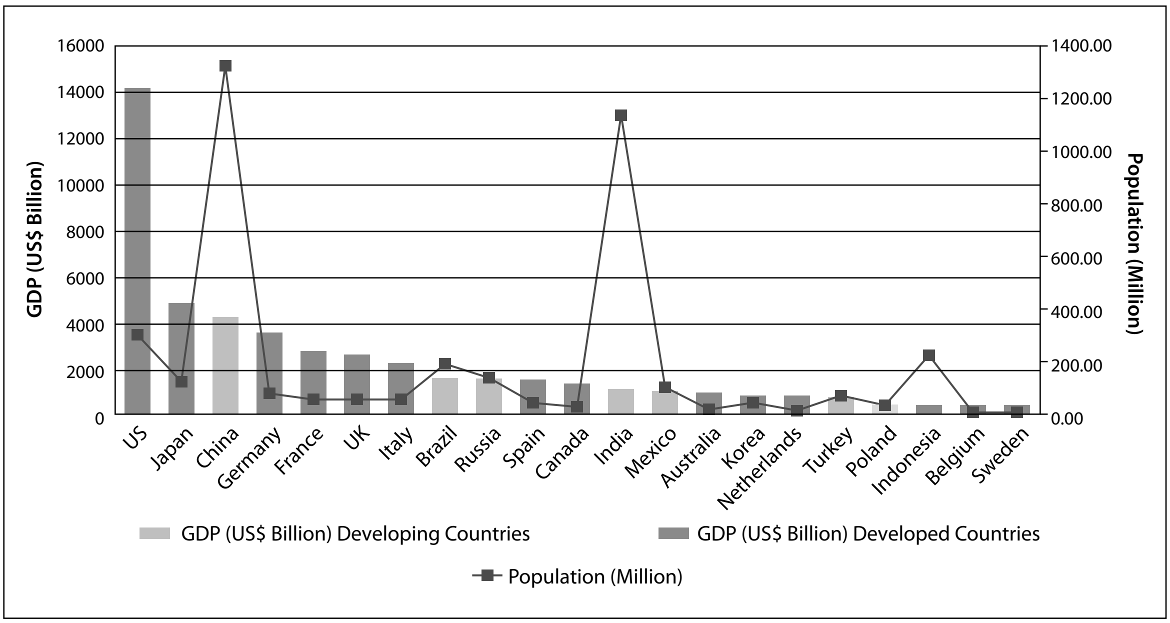
To investigate technological competitiveness in the telecom sector, the selected countries were compared in terms of the following indicators: *telecom-related patent applications by country of origin*, *relative specialization index* (RSI) (World Intellectual Property Organization [WIPO], 2009) for telecom technology, *telecom equipment exports*, *telecom equipment imports*, and the *telecom trade competitiveness index* (TTCI) (Momaya &

Goyal, 2007). The overall technological competitiveness was then defined with the newly introduced *composite technological competitiveness index* (CTCI). Similarly, technological competitiveness related to the telecom sector was defined with the newly introduced *composite telecom technological competitiveness index* (CTTCI).

Finally, technological competitiveness was analyzed with respect to overall competitiveness by plotting CTCI vs. COCI for all the selected countries. For the telecom sector, the telecom technology specific competitiveness was analyzed with respect to the overall technological competitiveness by plotting CTTCI vs. CTCI. The data in the analysis were taken only up to 2008, the year of major discontinuity; after 2008, volatility has been quite high.

Overall Competitiveness Assessment

When comparing national competitiveness, nations should be grouped with regard to similarities in terms of economic scale and structure (Cho & Moon, 2005). If the two main aspects of economic scale and structure, namely GDP and population, are considered, the analysis of the data for the top 21 countries enabled first-hand estimation of the technological competitiveness of these countries (especially in the telecom sector) and the standing of India in the comparison. Figure 1 shows a plot of the GDP and the population of the top 21 countries for the year 2008, arranged in decreasing order of GDP. To facilitate the comparison, the same order of the countries has been used in all the subsequent figures for other indicators.

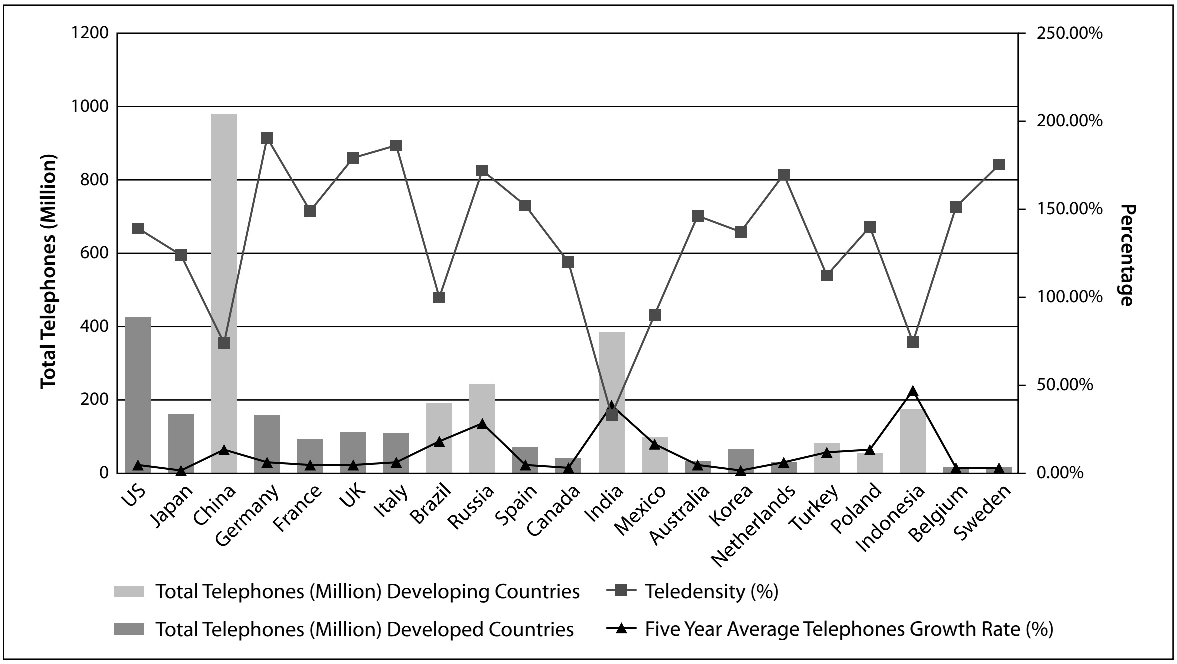


Note. Data source: World Bank (2013).

Figure 1. GDP and population of top 21 countries for year 2008.

For the year 2008, the combined GDP of the top 21 countries covers more than 80% of the world's GDP, and the combined population of these countries covers more than 60% of the world's population, thereby providing a reasonable representation of the world scenario. Figure 1 shows the developing and developed countries in different colors. The 13 developed countries (viz., the United States of America, Japan, Germany, the United Kingdom, France, Italy, Spain, Canada, Korea, Australia, the Netherlands, Belgium, and Sweden) represent about 62% of the world GDP and about 13% of the world population. In contrast, the eight developing countries (viz., China, Brazil, Russia, India, Mexico, Turkey, Poland, and Indonesia) represent about 19% of the world GDP and about 49% of the world population.

To assess the telecom services in all 21 countries, Figure 2 shows a plot of total telephones, teledensity, and 5-year average telephones growth rate for the year 2008. In this case, the developed countries have already seen a significant growth in the telecom services, as teledensity had reached beyond 100%. The combined telecom subscriber base of developed countries from this list is 1325 million, which is 25% of the world telecom subscriber base. The combined teledensity of these developed countries is 150% as against the world teledensity of 79%. Similarly, the combined telecom subscriber base of the developing countries from this list is 2207 million, which is 42% of the world telecom subscriber base. The combined teledensity of these developing countries is 68% as against the world teledensity of 79%. Among these 21 countries, in terms of teledensity, India ranks lowest with 34%, and China stands next at 74%.



Note. Data source: ITU (2009).

Figure 2. Total telephones, teledensity, and 5-year average telephones growth rate of the top 21 countries by GDP for year 2008.

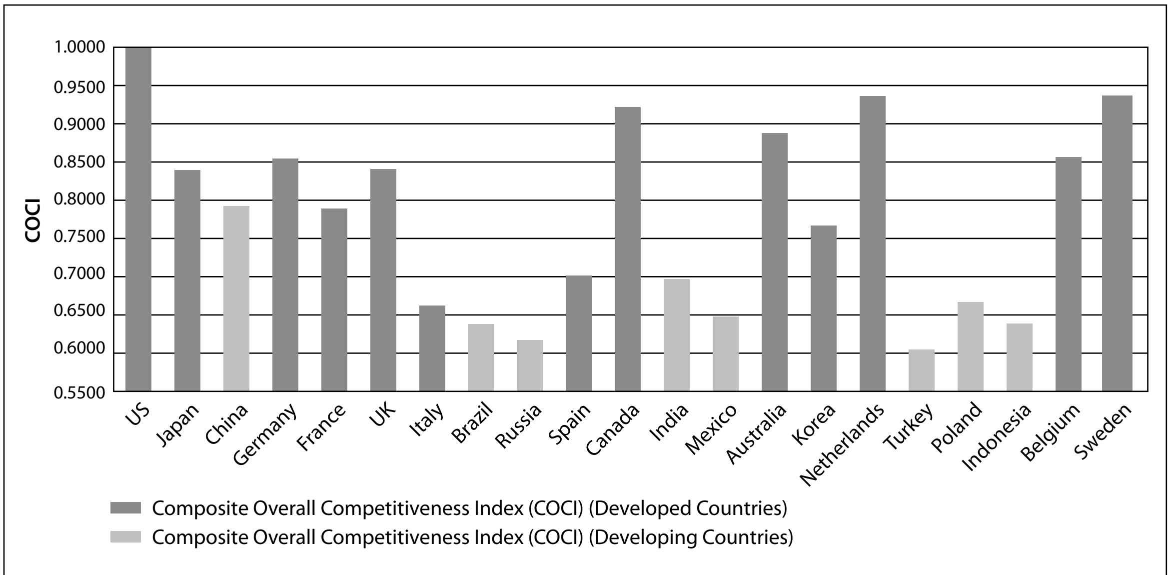
Figure 1 shows that the developed countries are already at a very high teledensity level with a much lesser population as compared to the developing countries. The 5-year average telephones growth rate is very low for the developed countries as compared to the developing countries. Within these 21 countries, this rate varies between 1%-6% for developed countries and between 12%-46% for developing countries. This rate is highest at 46% for Indonesia, followed by 39% for India and 29% for Russia. Thus, a significant growth in the sector is poised to happen in the coming years for the developing nations. However, unhindered growth of the segment will depend on the countries' ability to provide the necessary innovative and cost-efficient services and service competitiveness.

Overall Country Competitiveness Index

A number of organizations have conducted overall competitiveness studies over the past few years. Some of the important recent studies are the WEF (2009), IMD (2009), and *Institute for Industrial Policy Studies* (IPS, 2010). Each of these studies has presented the overall competitiveness score for different countries. While the WEF (2009) considered 134 countries, the IMD (2009) considered 55 countries, and the IPS (2010) considered 65 countries.

Each of the three competitiveness reports has its own perspectives when indexing the overall competitiveness of countries. The WEF (2009) considered: (a) basic requirements such as institutions, infrastructure, macro-economic stability, health, and primary education for the factor-driven economies; (b) efficiency enhancers such as higher education and training, goods market efficiency, labor market efficiencies, financial market sophistication, technological readiness, and market size for efficiency-driven economies; and (c) innovation and sophistication factors such as business sophistication and innovation for innovation-driven economies. The IPS (2010) measured both the scope (encompassing both the domestic and international context) and the source of national competitiveness (encompassing both physical and human factors). Physical factors included factor conditions, demand conditions, related industries, and business contexts, while human factors included workers, politicians and bureaucrats, entrepreneurs, and professionals. The IMD (2009) took into account a number of variables under the headings of economic performance, government efficiency, business efficiency, and infrastructure.

With the objective of holistic summarizing and giving due weighting to the extensive work already carried out in these major worldwide overall competitiveness studies, a derived *composite overall competitiveness index* (COCI) is now introduced. For the present analysis of the selected 21 countries, the competitiveness scores from each of the reports were considered with equal weighting. A COCI was calculated by taking the average of the normalized competitiveness scores from all three studies for all 21 selected countries. Figure 3 shows the COCI of all the selected countries.



Note. Data sources: WEF (2009), IPS (2010), and IMD (2009).

Figure 3. Composite overall competitiveness index (COCI).

Figure 3 shows that the highest competitiveness index is for the United States of America (1.0000), followed by Sweden (0.9370), the Netherlands (0.9366), Canada (0.9226), Australia (0.8883), Belgium (0.8571), Germany (0.8552), the United Kingdom (0.8417), and Japan (0.8399). All of these are developed countries. Among the developing countries, China is ahead with a value of 0.7929, followed by India (0.6973), Poland (0.6668), Mexico (0.6479), Indonesia (0.6392), Brazil (0.6391), Russia (0.6182), and Turkey (0.6039). Figure 3 also shows that the developed countries Korea (0.7664) and Spain (0.7010) lie between China and India, and Italy (0.6621) lies between Poland and Mexico.

Technological Competitiveness Assessment

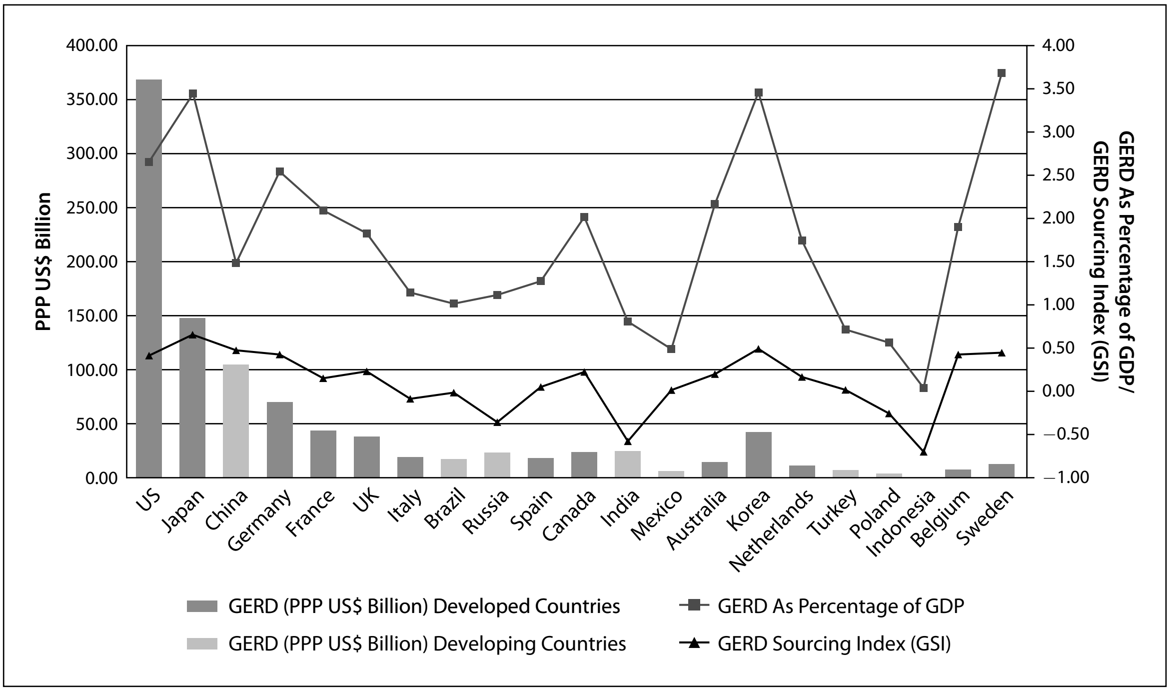
The technological competitiveness assessment for the selected countries is carried out using the following indicators.

Gross domestic expenditure on R&D (GERD) statistics

GERD is one of the important indirect indicators of technological competitiveness, more on the input side. The higher the GERD, the greater the technological competitiveness of a country. The specific GERD indicators considered here are the GERD in PPP US$, the GERD as percentage of the GDP, and the GSI. The GSI shows the R&D interest of business or government sources in a country and is here mathematically defined as follows:

$$GSI = \frac{(GERD\ financed\ by\ business - GERD\ financed\ by\ government)}{(GERD\ financed\ by\ business + GERD\ financed\ by\ government)}.$$

The *GSI* varies between +1 and -1; the higher the figure, the higher the business-financed R&D. Since in the long run the business interest is more sustainable, a positive and higher *GSI* may indicate a greater and more sustainable technological competitiveness. Figure 4 shows these measures for the top 21 countries by GDP.



Note. (a) GERD (PPP US$ Billion) and GERD As Percentage of GDP are for the year 2007 except for Italy (2006), Brazil (2006), Mexico (2005), Australia (2006), and Indonesia (2005). Similarly, GERD Sourcing Index (GSI) is for the year 2007, except for Germany (2006), France (2006), Italy (2006), Brazil (2006), Spain (2006), India (2004), Mexico (2005), Australia (2006), the Netherlands (2003), Indonesia (2001), Belgium (2005), and Sweden (2005). (b) Data source: United Nations Educational, Scientific and Cultural Organization (UNESCO, 2013).

Figure 4. Gross domestic expenditure on R&D (GERD) statistics.

Figure 4 shows that, in absolute terms, for the year 2007, the United States of America was the biggest R&D investor with a value of about PPP US$369 billion, followed by Japan (PPP US$148 billion), China (PPP US$105 billion), Germany (PPP US$70 billion), France (PPP US$43 billion), and Korea (PPP US$42 billion). In terms of GERD as percentage of GDP, for the year 2007, Sweden tops the chart with a value of 3.68%, followed by Korea (3.47%), Japan (3.45%), the United States of America (2.67%), and Germany (2.55%). The *GSI* was the highest for Japan with a value of about 0.67 (year 2007), followed by Korea (0.50, year 2007), China (0.48, year 2007), Sweden (0.45, year 2005), Germany (0.42, year 2006), Belgium (0.42, year 2005), and the United States of America (0.41, year 2007). This indicates that for most of the developed countries, the R&D interest of business is significantly higher than the government's.

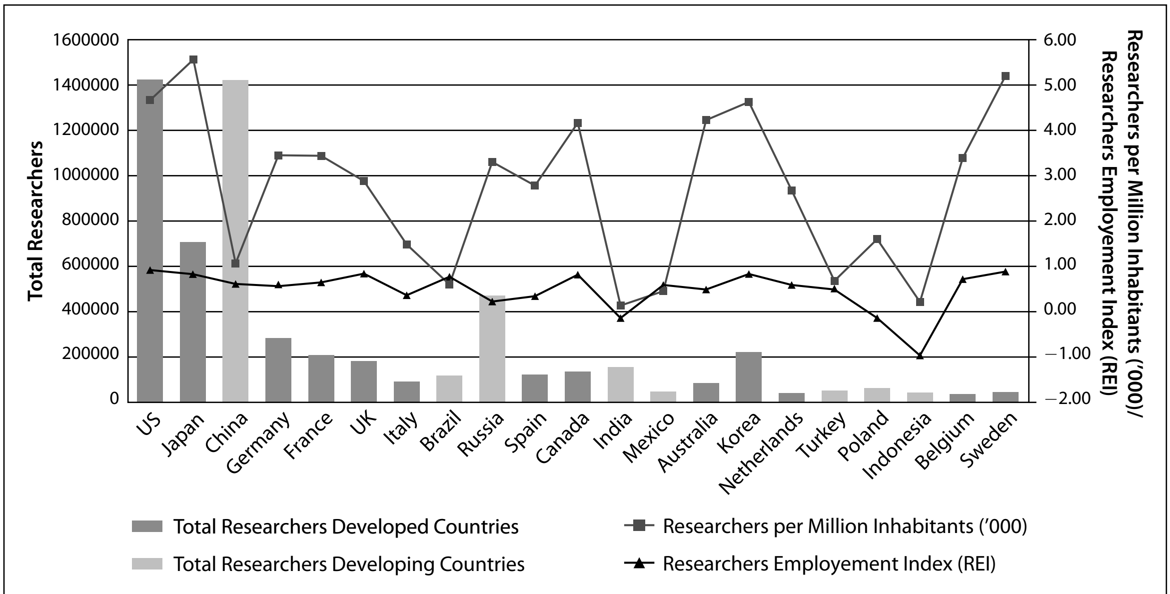
In the case of India, for the year 2007, the GERD was about PPP US$25 billion, which is a lowly 0.80% of the GDP. Even for other similar developing countries, the GERD as percentage of the GDP was much higher with China at 1.49% (year 2007), Russia at 1.12% (year 2007), and Brazil at 1.02% (year 2006). The *GSI* was also lowest for India at -0.58 (year 2004) as compared to China (0.48, year 2007), Mexico (0.01, year 2005), Turkey (0.01, year 2007), Brazil (-0.02, year 2006), Poland (-0.26, year 2007), and Russia (-0.36, year 2007). As far as the developing countries are concerned, by and large, the government is spending more for R&D than business.

Researcher statistics

The statistics related to the number of researchers can also act as one of the surrogate measures of technological competitiveness. The more the researchers, the greater the technological competitiveness of a country. The specific indicators considered here are total number of researchers (full-time equivalent), number of researchers per million inhabitants, and the REI. The REI shows the researchers' hiring interest of business as compared to the government in a country and is here mathematically defined as follows:

$$REI = \frac{(Researchers\ employed\ by\ business - Researchers\ employed\ by\ government)}{(Researchers\ employed\ by\ business + Researchers\ employed\ by\ government)}.$$

The REI varies between +1 and -1; the higher the figure, the higher the researchers' hiring interest of business. Since in the long run the business interest is more sustainable, a positive and higher REI may indicate a greater and more sustainable technological competitiveness. Figure 5 shows these measures for the top 21 countries by GDP.



Note. (a) Total Researchers and Researchers per Million Inhabitants are for the year 2007 except for the United States of America (2006), France (2006), Italy (2006), Brazil (2006), Canada (2005), India (2005), Mexico (2005), Australia (2006), and Indonesia (2001). Similarly, the Researcher Employment Index (REI) is for the year 2007 except for the United States of America (2002), France (2006), Brazil (2006), Canada (2005), India (2005), Mexico (2005), Australia (2006), and Indonesia (2001). (b) Data source: UNESCO (2013).

Figure 5. Researchers' statistics.

Figure 5 shows that, in absolute terms, the United States of America has the largest number of researchers, with a value of about 1.43 million, followed by China (1.42 million, year 2007), Japan (0.71 million, year 2007), Russia (0.47 million, year 2007), Germany (0.28 million, year 2007), and Korea (0.22 million, year 2007). However, in terms of the number of researchers per million inhabitants, Japan tops the chart with a value of 5573 (year 2007), followed by Sweden (5215, year 2007), the United States of America (4663, year 2006), Korea (4627, year 2007), Australia (4231, year 2006), and Canada (4157, year 2005). The *REI* has been the highest for the United States of America (0.91, year 2002), followed by Sweden (0.88, year 2007), Japan (0.87, year 2007), the United Kingdom (0.83, year 2007), Korea (0.826, year 2007), and Canada (0.81, year 2005). This indicates that for most of the developed countries, the researchers' hiring interest of business is much higher than the government's.

As far as the developing countries are concerned, the total number of researchers is greater for China (1.42 million, year 2007), followed by Russia (0.47 million, year 2007), India (0.15 million, year 2005), and Brazil (0.12 million, year 2006). India stands lowest in terms of the number of researchers per million inhabitants with a value of 137 (year 2005), compared to its peers like Russia (3305, year 2007), China (1071, year 2007), and Brazil (629, year 2006). The *REI* is also the lowest for India (-0.14, year 2005), compared to its peers like Brazil (0.77, year 2006), China (0.61, year 2007), and Russia (0.22, year 2007). Thus, India has a negative *REI*, compared to the fairly positive *REIs* of its peer developing countries, which indicates that Indian business is yet to take a serious interest in researchers' hiring compared to the government's.

Patent statistics

The patent statistics are yet another set of statistics that indicate the technological competitiveness of a country. The higher the number of patents filed and granted, the greater the technological competitiveness. The important measures covered here are patent applications by patent office, residents' share in the patent applications by patent office, patents in force by patent office, patent applications by country of origin, residents' patent filing per US$ billion GDP, residents' patent filing per million population, and residents' patent filing per US$ million R&D expenditure.

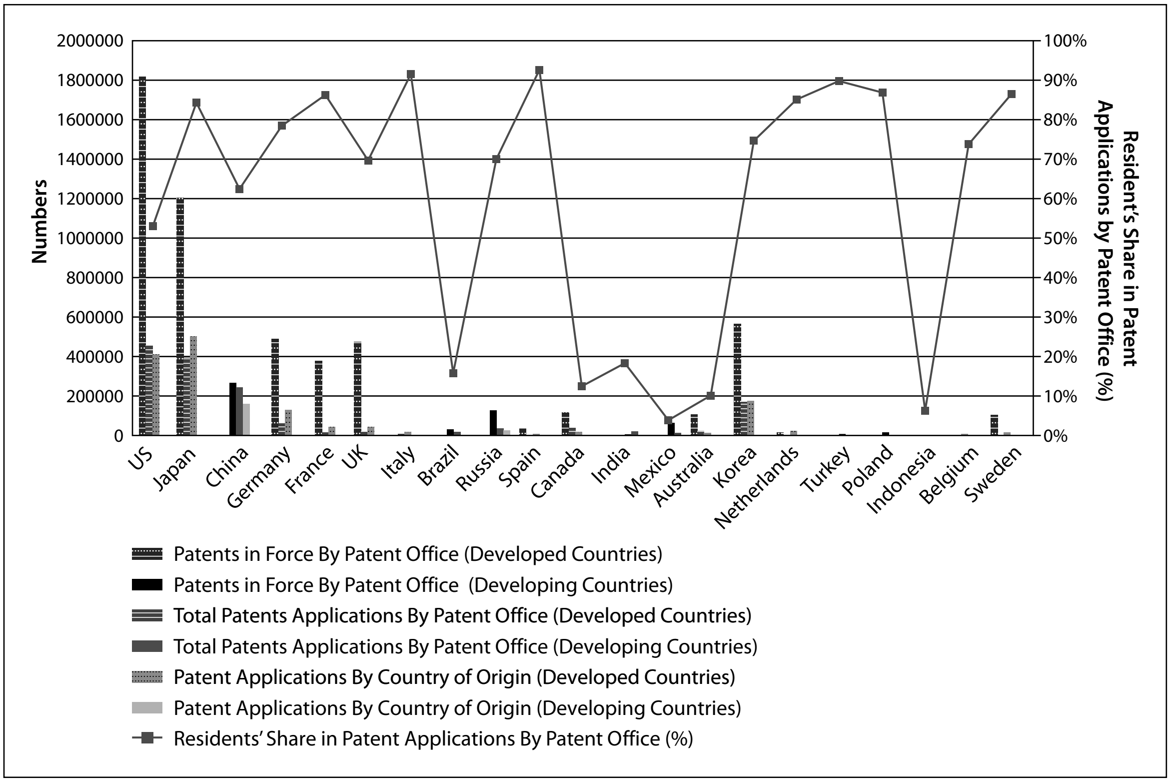
The total patent office statistics of a country indicate the ruggedness of the patent regime in the country. The residents' share in the patent office statistics and the patents by country of origin show the technological capabilities of a country. The residents' patent filing per US$ billion GDP, residents' patent filing per million population, and residents' patent filing per US$ million R&D expenditure indicate the patent intensity of a country. For the telecom sector, the measures covered are the telecom-related patent applications by country of origin and the relative specialization index (RSI) (WIPO, 2009) for telecom technology.

WIPO (2009) has mathematically defined RSI:

$$RSI = log\left[\frac{\dfrac{F_{c,t}}{\sum_{c} F_{c,t}}}{\dfrac{\sum_{t} F_{c,t}}{\sum_{c,t} F_{c,t}}}\right],$$

where F is the number of Patent Cooperation Treaty (PCT) applications published in a given technology field and country of origin and c and t are indexes for the country of origin and technology field, respectively. The RSI measures a country's degree of concentration of PCT filings (based on published applications) in a particular technology. A positive RSI value for a particular technology implies that the country has a relatively high share of PCT applications in that technology (i.e., it has a higher share in PCT applications in this technology relative to its share in all technologies). Similarly, a negative RSI value implies that the country has a relatively low share of PCT applications in that technology. Thus, while the total number of patent families indicates the overall strength of the country's R&D activities, the RSI provides an indication of the country's R&D strength in a particular technology. Figures 6, 7, and 8 show these measures for the top 21 countries by GDP.

Figure 6 shows that the patent activity is the most prominent in the two largest economies of the world, namely the United States of America and Japan. The patent applications by the patent office, for year 2007, are the highest in the United States of America (456154), followed by Japan (396291), China (245161), Korea (172469), and Germany (60992). The residents' share in patent applications by the patent office, for year 2007, in these countries, are the United States of America (52.91%), Japan (84.15%), China (62.43%), Korea (74.62%), and Germany (78.46%). The residents' share percentage, for year 2007, looks much higher in other countries like Spain (92.5%), Italy (91.41%), Turkey (89.56%), Poland (86.89%), Sweden (86.39%), France (86.05%), and the Netherlands (85%), but the absolute number of patent applications are negligible compared to those of the leading countries. This finding indicates that the patent regime is ahead in countries like the United States of America, Japan, China, Korea, and Germany as compared to other countries. The patent applications by country of origin, for year 2007, are the highest in Japan (501270), followed by the United States of America (409952), Korea (174896), China (160523), and Germany (130207). This shows that Japan leads the pack of the most technologically capable countries, followed by the United States of America, Korea, China, and Germany.

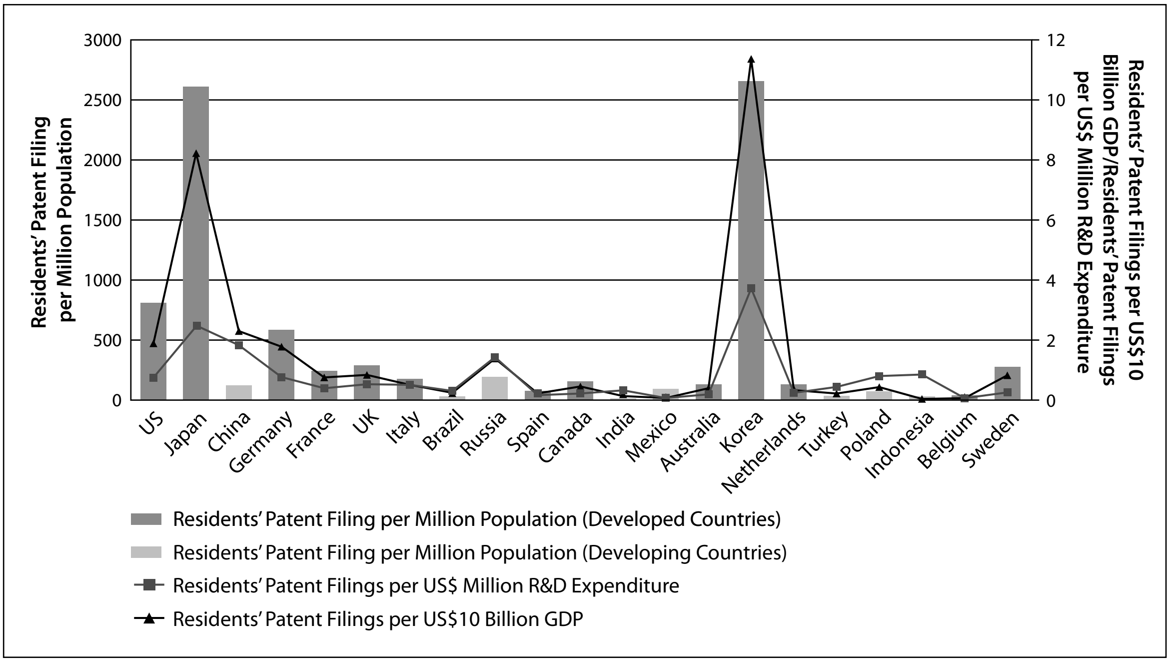


Note. (a) Patents in Force by Patent Office are for the year 2007 except for France (2006), the United Kingdom (2004), Italy (not available), Brazil (2006), India (2004), Indonesia (not available), Belgium (2006), and Sweden (2005). Similarly, Total Patent Applications and Residents' Share (%) in Patent Applications by Patent Office are for the year 2007 except for Brazil (2006), India (2006), and Indonesia (2006). The Patent Applications by Country of Origin are all for the year 2007. (b) Data source: WIPO (2009).

Figure 6. Patent statistics.

In contrast, the patent regime in countries like Belgium, Turkey, the Netherlands, Poland, Sweden, Spain, and Indonesia looks to be extremely weak, as the patent applications in their respective patent offices do not even reach the figure of 5000 for the year 2007. Similarly, countries like Indonesia, Brazil, Mexico, Turkey, Poland, and India appear to be technologically least capable, as patent applications originating from these countries do not even reach the figure of 5000 for the year 2007. India, with 28940 patent applications (year 2006) in its patent office and 3882 total patent applications (year 2007) originating from the country to any patent office in the world, stands very low as compared to its peer countries like China (245161 by office, 160523 by origin) and Russia (39439 by office, 28646 by origin), but it is slightly ahead of Brazil 24074 by office, 1049 by origin).

Figure 7 shows that the residents' patent filings per million population, for year 2007, is the highest for Korea (2656.04), followed by Japan (2610.13), the United States of America (800.17), Germany (581.67), the United Kingdom (284.83), Sweden (276.23), and France (238.58). Similarly, the residents' patent filings per US$10 billion GDP, for year 2007, is the highest for Korea (11.39), followed by Japan (8.24), China (2.28), the United States of America (1.86), Germany (1.75), Russia (1.40), the United Kingdom (0.84), Sweden (0.81), and France (0.76). The residents' patent filings per US$ million R&D expenditure, for year 2007, is again the highest for Korea (3.70), followed by Japan (2.48), China (1.82), Russia (1.41), Germany (0.74), the United States of America (0.72), and the United Kingdom (0.50) (Indonesia and Poland are not included in the comparison because of their very low absolute patent numbers and very low GERD). These statistics indicate that Korea shows the most intense technological capabilities with a high patent numbers in spite of low population, GDP, and GERD. Japan is the second such country. From the group of developing countries, China and Russia are included in the top patent intensity countries.

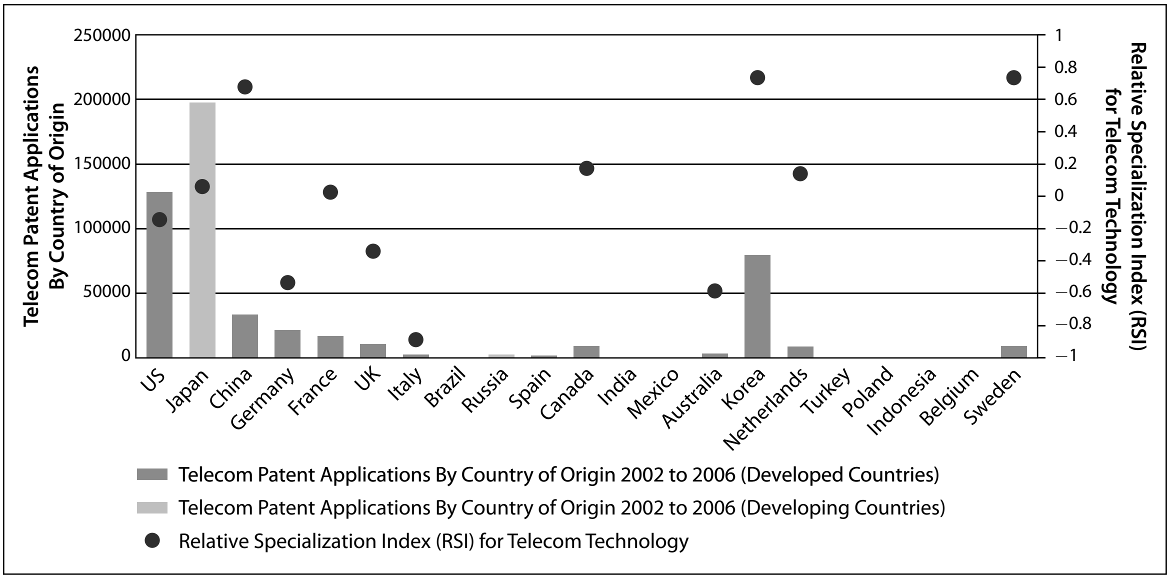


Note. (a) Residents' Patent Filings per Million Population and Residents' Patent Filings per US$10 billion GDP are for the year 2007 except for Brazil (2006), India (2006), and Indonesia (2006). Similarly, Residents' Patent Filings per US$ million R&D Expenditure are for the year 2007 except for Brazil (2006), India (2005), Mexico (2006), and Indonesia (2002). (b) Data source: WIPO (2009).

Figure 7. Patent intensity statistics.

For India, the patent filings per million population, per US$10 billion GDP, and per US$ million R&D expenditure, for year 2006, are extremely low with figures of 4.79, 0.20, and 0.29, respectively, as compared to the same triplet for its peer countries like China (116.10, 2.28, 1.82) (year 2007), Russia (193.56, 1.40, 1.41) (year 2007), and Brazil (20.12, 0.23, 0.29) (year 2006). This shows a very low technological capability for India as compared to its peer countries.

In the telecom sector, the Figure 8 shows the telecom patent applications by country of origin from year 2002 to 2006 and the *RSI* for the top 21 countries by GDP. Figure 8 shows that the highest telecom technology patent applications for the period 2002-2006 are for Japan (197719), followed by the United States of America (128177), Korea (79456), China (33527), Germany (21293), France (17389), the United Kingdom (9961), the Netherlands (9140), and Sweden (9110). The *RSI* for telecom technology for the period 2003-2006 is the highest for Korea (0.74) and Sweden (0.74), followed by China (0.68), Canada (0.18), the Netherlands (0.14), Japan (0.06), and France (0.03). These countries can be considered as specializing in telecom technology. The *RSI* is negative in the rest of the countries. For the United States of America, even though the *RSI* is -0.14, the number of telecom technology-related patent applications is much higher than those of Korea and Sweden. This means that in spite of the United States of America not concentrating particularly on telecom technology area, its patents activity in this area is still at the second highest level.



Note. (a) Telecom Patent Applications numbers are not available for Mexico, Turkey, and Indonesia. The *RSI* for Australia is for the period 2001-2005. The *RSI* is not available for Brazil, Russia, Spain, India, Mexico, Turkey, Poland, Indonesia, and Belgium. (b) Data source: WIPO (2009).

Figure 8. Telecom patent statistics for period 2002-2006.

In the developing countries, China has emerged specializing in this area. For India, the telecom technology-related patent applications are a mere 140 in this period; India is, thus, the lowest among the countries, as its peer countries like China, Russia, and Brazil have 33527, 1991, and 441, respectively.

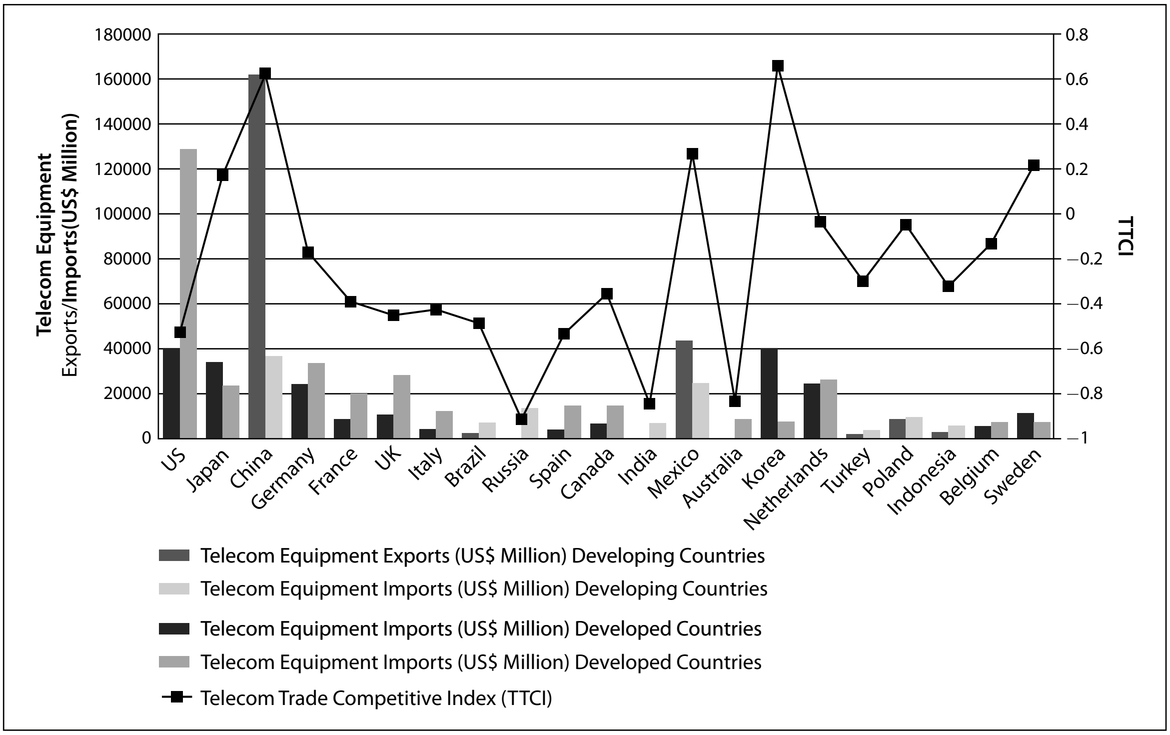
Telecom equipment exports, imports, and telecom trade competitiveness index (TTCI)

For technological competitiveness in the telecom sector, some of the surrogate measures are the telecom equipment exports, imports, and the TTCI (Momaya & Goyal, 2007). The greater telecom equipment exports and TTCI, the greater technological competitiveness (specifically in the telecom sector). The TTCI shows the capability of a country to net export the telecom equipment. The mathematical definition of this index is as follows:

$$TTCI = \frac{(Telecom\ equipment\ export - Telecom\ equipment\ import)}{(Telecom\ equipment\ export + Telecom\ equipment\ import)}.$$

The *TTCI* varies between +1 and -1; the higher the figure, the higher ability of net export of the telecom equipment.

Figure 9 shows these measures for the top 21 countries by GDP for the year 2008. Figure 8 shows that the biggest exporter of the telecom equipment is China with a massive value of US$162 billion, followed by Mexico (US$44 billion), Korea (US$40 billion – year 2007), the United States of America (US$40 billion), and Japan (US$34 billion). The telecom equipment export for India is at the rock bottom figure of US$620 million only. Similarly, for the year 2008, the biggest importer of telecom equipment is the United States of America with a value of US$129 billion, followed by China (US$37 billion), Germany (US$34 billion), the United Kingdom (US$29 billion), and the Netherlands (US$27 billion). The Indian telecom equipment import figure for year 2008 is US$7 billion. Thus, the top countries involved in the telecom equipment trade are China, Mexico, Korea, the United States of America, Japan, Germany, the United Kingdom, and the Netherlands.



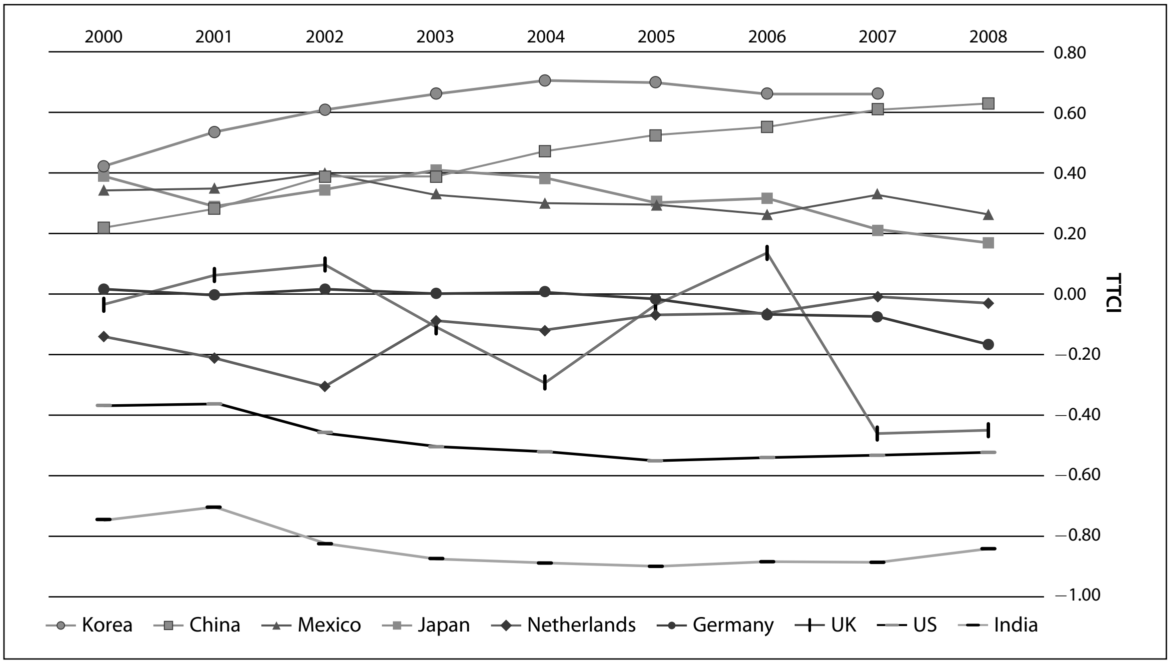
Note. (a) The figures are for year 2007 in the case of Korea and Spain. (b) Data source: United Nations Commodity Trade (UN Comtrade, 2013).

Figure 9. Telecom equipment exports, imports and Telecom Trade Competitiveness Index of the top 21 countries by GDP for the year 2008.

The *TTCI* among these major countries for year 2008 is the best for Korea at 0.66 (year 2007), followed by China (0.63), Mexico (0.27), Japan (0.17), the Netherlands (-0.03), Germany (-0.17), the United Kingdom (-0.45), and the United States of America (-0.52).

Figure 10 shows the *TTCI* trends of these countries (and India) over the last nine years. Figure 10 shows that Korea has maintained the highest *TTCI* over the last few years. Moreover, over the years, Korea, China, Mexico, and Japan have shown a consistently positive *TTCI*. There has been a steady rise of *TTCI* for China, from the fourth rank to almost the top of the table. The Netherlands has also shown a steady rising trend. While most of the countries have shown steady trends, the *TTCI* for the United Kingdom has been varying considerably over the years, even going positive for some of those years.

India's *TTCI* trends show a steady pattern nearing the lowest possible value of -1 with value of -0.84 for year 2008. The near -1 value of *TTCI* for India shows the very low capability of the country for the export of telecom equipment, thereby signaling low technological competitiveness in the telecom sector. Another interpretation of this figure depicts the heavy dependence of Indian telecom operators on foreign technology. In the case of other developing countries, the *TTCI* has been almost near -1 for Russia (-0.91 for year 2008).



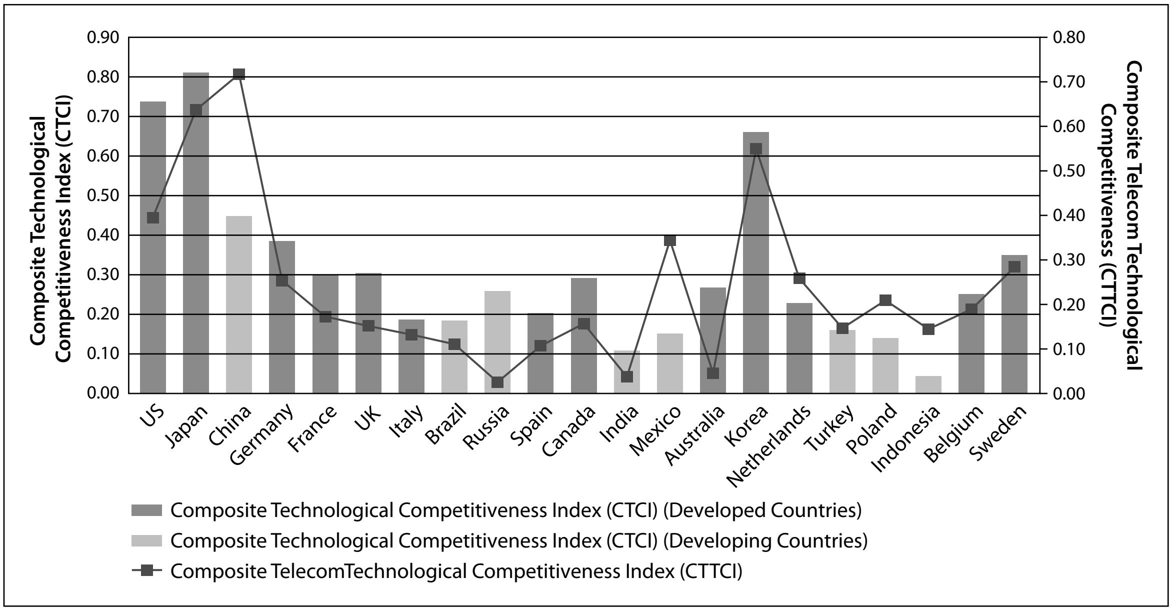
Note. Data source: UN Comtrade (2013).

Figure 10. Telecom *TTCI* trends of top telecom equipment trading countries (and India).

Technological competitiveness index

With some of the measures of technological competitiveness under investigation, overall technological competitiveness is now measured in terms of a composite technological competitiveness index (CTCI), which is calculated as the average of the normalized values of measures like GERD in PPP US$, GERD as percentage of GDP, *GSI*, number of researchers (full-time equivalent), number of researchers per million inhabitants, *REI*, patent applications by patent office, patent applications by country of origin, patents in force by patent office, residents' patent filing per US$ billion GDP, residents' patent filing per million population and residents' patent filing per US$ million R&D expenditure. Similarly, the technological competitiveness of the telecom sector is measured in terms of a composite telecom technological competitiveness index (CTTCI), which is calculated as the average of the normalized values of measures like telecom exports, *TTCI*, and telecom patent applications by country of origin.

Figure 11 shows the CTCI and CTTCI of all the selected countries. Figure 11 shows that the CTCI is the highest for Japan (0.81), followed by the United States of America (0.74), Korea (0.66), China (0.45), Germany (0.39), Sweden (0.35), the United Kingdom (0.30), France (0.30), and Canada (0.29). India's CTCI is 0.11, which is the second lowest among the selected group of countries, ahead of Indonesia (0.04). India's peer countries like China (0.45), Russia (0.26), and Brazil (0.18) are ahead.



Note. For the telecom sector, the CTTCI is the highest for China (0.72), followed by Japan (0.64), Korea (0.55), the United States of America (0.39), Mexico (0.35), Sweden (0.28), the Netherlands (0.26), Germany (0.25), Poland (0.21), France (0.17), Canada (0.16), and the United Kingdom (0.15). India's CTTCI is 0.03, which the second lowest among the selected group of countries, ahead of Russia (0.02). India's other peer countries like China (0.72) and Brazil (0.11) are ahead.

Figure 11. Overall technological competitiveness and telecom technological competitiveness.

Analysis of Technological Competitiveness and Overall Competitiveness

Since technological competitiveness provides long term sustenance to overall competitiveness (Banwet et al., 2003; Fagerberg, 1987; Ho, Wong, & Toh, 2005; Momaya & Ajitabh, 2005; OECD, 1997; Resende & Torres, 2008), it is relevant to analyze overall technological competitiveness and overall competitiveness together so that a clear picture of the sustainability of competitiveness can emerge. Figure 12 plots the CTCI vs. COCI for all the selected countries.

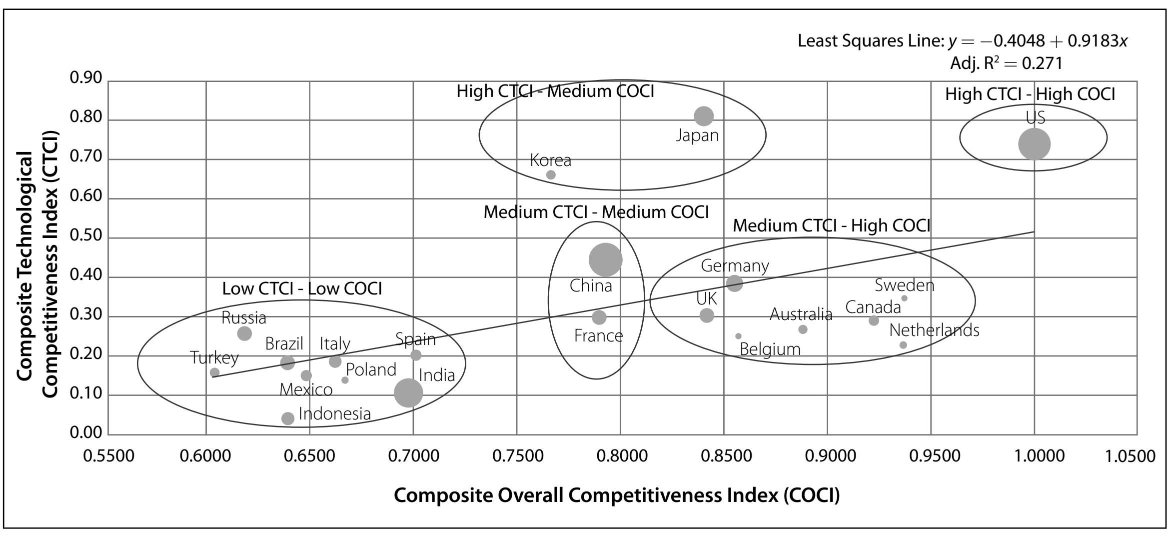


Figure 12. Technological and overall competitiveness matrix.

The size of the bubbles in the figure shows the size of the countries in terms of GDP and population (50% weighting to each). Figure 12 indicates that groups of countries show clear trends, namely High CTCI – High COCI, High CTCI – Medium COCI, Medium CTCI – High COCI, Medium CTCI – Medium COCI and Low

CTCI – Low COCI. Among the selected countries, the United States of America is the only country with High CTCI – High COCI and is ahead of the rest of the countries. Japan and Korea have High CTCI – Medium COCI. These countries, though being technologically very advanced, need to utilize their technological competitiveness towards long term overall competitiveness. China and France have Medium CTCI – Medium COCI. Russia, Spain, Italy, Brazil, Turkey, Mexico, Poland, India, and Indonesia have Low CTCI – Low COCI. Except Italy, these are developing countries. They are on the lower rung of the competitiveness ladder on both fronts.

The causality among the two dimensions is quite complex and beyond the scope of this study. However, we tried to measure association by using the bivariate linear regression and best-fitting regression line. The goodness of the line's fit was evaluated by the coefficient of determination (adjusted R^2); the same is given along with the equation in the bottom right corner of the figures.

Within its group, India is the second highest in overall competitiveness after Spain, but the second lowest in technological competitiveness after Indonesia. Thus, there is an urgent need for India to improve its technological competitiveness which becomes a lever to improve and sustain overall competitiveness. In terms of the size of the bubble signifying the GDP and population, the largest three bubbles are the United States of America, China, and India. The fact that China, in spite of being a developing country, has already progressed towards both Medium CTCI and Medium COCI, shows the urgent need for India to make progress.

Analysis of Telecom Technological Competitiveness and Overall Technological Competitiveness

To analyze the positions of the countries in the telecom technology sector, the CTTCI and CTCI are plotted together in Figure 13. The size of the bubbles in the figure shows the size of the countries in terms of GDP and population (50% weighting to each). Slightly different clusters emerge among groups of countries, namely High CTTCI – High CTCI (Japan and Korea), High CTTCI – Medium CTCI (China), Medium CTTCI – High CTCI (the United States of America), Medium Low CTTCI – Medium Low CTCI (Sweden, Germany, the Netherlands, Belgium, France, Canada, the United Kingdom, Mexico, Poland, Turkey, Italy, Brazil, Spain, Australia, and Russia) and Low CTTCI – Low CTCI (Indonesia and India). Thus, in spite of being among the largest three bubbles in the figure, India is on the lowest rung and needs to catch up massively in the telecom technological competitiveness sector as well. A high coefficient of determination (adjusted R^2) hints at the need to enhance overall technological competitiveness to catch up on telecom industry competitiveness.

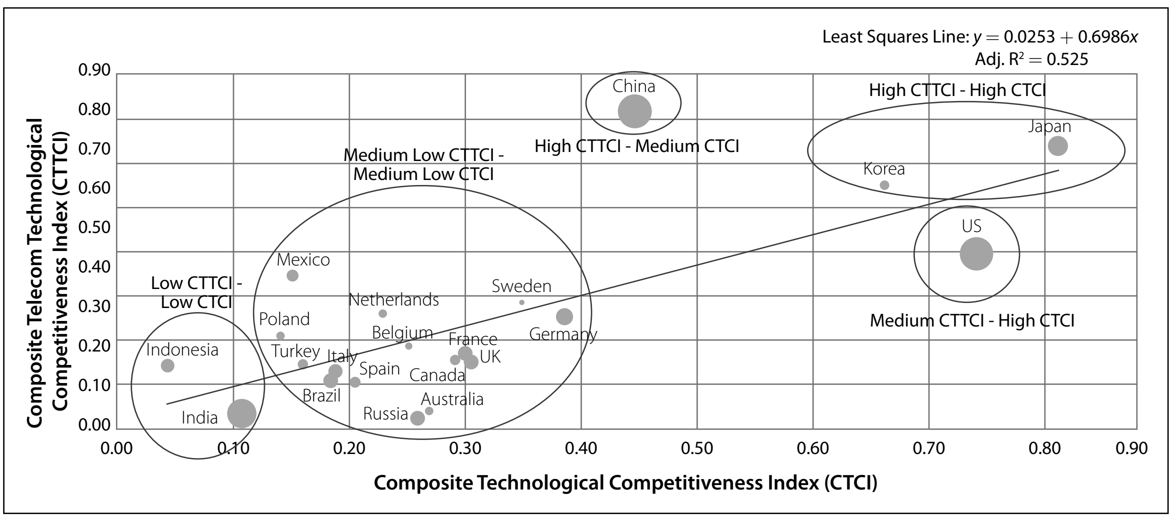


Figure 13. Telecom technological competitiveness and overall technological competitiveness matrix.

Conclusion and Implications

The key purpose of this paper was to develop better indices of overall and technological competitiveness and to develop comparative views of the major countries of the world. The paper provides a fair representation of the world scenarios by considering the top 21 countries (in terms of GDP and population) for their overall competitiveness as well as technological competitiveness. Technological competitiveness is often a key driver of and provides long-term sustenance to overall competitiveness (Banwet et al., 2003; Momaya & Ajitabh, 2005; OECD, 1997).

The findings shown in Figure 12 also indicate that most of the developed countries that have high overall competitiveness have also high or medium technological competitiveness. This implies that most of the countries with high overall competitiveness have already paid attention to their technological competitiveness. The three clear leaders in terms of technological competitiveness are Japan, the United States of America, and Korea. Of those, Japan and Korea also figure in the top technological competitiveness group in the telecom sector. The distinct clusters of Japan, Korea, and China in Figure 13 are indicative of the role played by competitiveness in telecom technology for their progress in overall technological competitiveness.

Among the large emerging countries, China seems to have shown the most effective catch-up. While China has attained medium overall competitiveness and medium technological competitiveness, it has attained the highest level of technological competitiveness in the telecom sector, even when all the developed countries are also included in the analysis. India's other peer countries are mainly Russia and Brazil. While so far India has been no match to China in many competitiveness aspects, it is ahead of Russia and Brazil in terms of overall competitiveness. In terms of technological competitiveness, however, not only is India behind Russia and Brazil, it is also on the lowest rungs for almost all the technological competitiveness measures. India figures on the second lowest level among the 21 selected countries. Even in the telecom sector, India figures on the second lowest level among the 21 selected countries for technological competitiveness.

To evidence sustainable progress in overall competitiveness, India needs to attach high priority to technological competitiveness so as to catch up. Because India is among the top three countries in terms of its GDP and population (with 50% weighting each) (the other two are the United States of America and China), it should try to contribute its fair share to global innovation, products, and R&D. In countries where technological advancements have not reached a critical value (mainly emerging countries), the input efforts have come more from the government than from the business sector (Lee & Han, 2002). However, in most of the developed countries, the input efforts have shifted from the government to the business sector, which is more sustainable. This is evidenced in the trends in *GSI* and *REI* (see Figures 4 and 5).

As far as India is concerned, it is important to study the problem of low technological competitiveness, especially in the Indian telecom sector, in a systemic manner (Mittal, Momaya, & Sushil, 2009; Momaya & Goyal, 2007) and devise corrective measures for the various actors involved in the system. Though the role of government looks to be more prominent in the initial period, the lead for the break-out towards the virtuous spiral needs to come from local firms (Hnyilicza, 2008). India must attempt to scale up its technological contribution across the spectrum (from use and knowledge-creation to effective exploitation by international diffusion) now. The opportunity window is limited, and capability building can be very demanding. However, to stretch up on the competitive stages (Momaya, 2011), there could be some trade-offs such as: (a) a narrow scope on acquiring customers vs. a broad scope in capturing value through integration, (b) short-term opportunity-driven profits vs. capability-driven competitiveness processes (Umamaheswari & Momaya, 2008), and (c) a domestic focus and international balance.

This quantitative paper offers major contributions to the field and implications for several stakeholders. The key contribution of the paper is in enhancing the methods to evaluate competitiveness (Momaya, 2001) at the intersection of country and industry competitiveness, including the development of several indices. The systematic accumulation and use of carefully selected data to develop rich snapshots of the current situation to be used by all stakeholders is a major strength of this paper. Among many stakeholders, political and business leaders are considered the most important in the current context. Hence, key implications are drawn mainly for them from the findings of the paper.

Since the domestic market provides the most important foundation for learning and capability building, and India is at a very critical stage of investing massively in telecom technology generation, this rare opportunity must be leveraged synergistically through close cooperation among all stakeholders. Industries or local firms may not feel comfortable taking the lead in massive investments in manufacturing or risky investments in R&D unless governments develop shared purposes and create long-term systems that encourage risk takers. Hence, there is an urgent need for policy correction, if this huge and growing industry is to be shifted from its sustained big drain on forex (see the very negative *TTCI* trends for India in Figure 10) to a creator of value, employment, and opportunities for indigenous industrial innovation.

Comparative perspectives from patterns in graphs provide important clues regarding the opportunities and challenges for competitiveness. The diagnostic nature of the paper does not permit empirical conclusions, but suggestions that build on the longitudinal factual perspectives can be useful. Rather than encouraging deficit-driven distorted growth in India and the telecom sector, political and industry leaders should take clues from leading emerging countries that have progressed through building technological capabilities to set relevant targets and incentivize rapid achievers. They should encourage technological capability building in relevant stakeholders. Because the biggest opportunity for capability building in the current liberalized era are for clusters and industries, large players such as service providers should take the lead in investments and leverage. The facts clearly hint at adverse positions for India, and there is an urgent need for the indigenous industries to generate technology, intellectual property (e.g., in terms of patents, publications), and products along with a robust manufacturing base to complement R&D. The newly introduced composite indices (COCI, CTCI, and CTTCI) can be further tested in different contexts and implemented in practice to understand trends and patterns of competitiveness.

Emerging countries have an enormous potential to move up the ladder of competitiveness to address the needs of their population, if leadership and cooperation drivers are developed adequately. The significant country competitiveness gains India made over the period 2005-2009, when the country went from 47th to 29th overall rank (Yadav & Momaya, 2010), were largely driven by factor conditions such as a young population and workers, since India has been ranked No. 1 since 2006 (IPS, 2006). Because competitiveness can be viewed as a marathon to achieve excellence, sustainability demands leadership that helps the shift towards the innovation-driven stage (Momaya, 2011). If the cooperation-driven stage is well addressed, investments can be made more sustainable to contribute much more to world production, trade and technology, which is a cherished competitiveness goal for pioneers in India.

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