# National Innovation System in the Era of Liberalization: Implications for Science and Technology Policy for Developing Economies

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Abstract:

The national system of innovations in the recent phase of globalization has undergone dramatic structural transformation. Innovations entails organizational as well as changes in the rules of the game. The history of economic development of the developing and newly industrializing economies shows that national systems of innovation have evolved keeping in view the most pressing requirements of the national economic development. The knowledge generation and transmission are the two essential characteristics of national innovation system that connects the users and producers of knowledge and also allows institutional arrangements to functions as a feedback system. The institutional arrangements are being altered substantially to allow capital to move freely across national borders on the one side and strict trade related intellectual property rights on the other. How these arrangements have affected the national system of innovation both in the developed and developing countries during the recent liberalisation phase of economic development? In this paper an attempt has been made to provide some plausible answers to this question. Input and output indicators have been used with a view to unravel the dramatic structural changes occurring both in the economic and innovation structure of the global economy. The internationalisation of R&D expenditure and its implications for revealed comparative advantage have been examined in order to understand the direction of change during the era of liberalisation. The suitable changes in the science and technology policy have been suggested to strengthen the national system of innovation for generating unique competitive advantage in the developing countries.

Key Words: National system of Innovation, structural transformation, input and output measures of innovations, revealed competitive advantage, public policy, internationalisation of R&D and intellectual property rights

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**1. Introduction**:

It is widely recognized that Knowledge is the most important source of economic development and change. Income differentials that exist across countries and over time have been essentially attributed to knowledge gaps. The industrially advanced countries continuously strive to push knowledge frontiers outward and consequently generate competitive advantage to forge ahead in economic activities. This process not only generates income gaps between the rich and the poor countries but also continuously adds to the gaps in capacity building in knowledge. The capacity to create knowledge that matter for economic development is mainly being developed within economic system and is called national system of innovations (NSI). The seminal contribution in this direction has done by Lundvall (1992) and Nelson (1993). The concept of NSI assumed significance and attracted attention of the large number of researchers and policy makers working in the areas of innovations and development economics both in the developed and developing economies after the publication of work by Lundvall and Nelson (Freeman, 1997; Mytelka and Smith, 2002; and Edquist and Hommen, 2006). The national systems of innovation that generates capacities to innovate new knowledge entails network of economic actors and institutions essentially coordinated by the Government. The NSI progressively generates dynamism in the productive economic activities, which usually culminates in developing and nurturing unique competitive advantage in economic activities and actors. The superior economic performance within the national economy encourages economic agents of production to expand operations at a global scale to further take advantage of home grown competitive advantages to exploit economies of scale of various kinds. The knowledge generation and transmission are the two essential characteristics of national innovation system that connects the users and producers of knowledge and also allows institutional arrangements to functions as a feedback system from top to bottom and vice versa. The channels and mechanisms that act as an agent of knowledge transmission both in the national economy and international economy are essentially common but differ in terms of costs. It is significant to note that national innovation system since its origin and evolution has strong learning linkage across national borders. The development in the institutional innovations in terms of transnational corporations that have contributed in rapid transmission and exploitation of knowledge across national borders and weakened their commitment to place of origin (Ruttan, 2001). According to Ruttan (2001), the national differences in terms of capacity to generate, transfer and absorb knowledge continue to remain a matter of prime importance. The rate and direction of knowledge development and change essentially remained very much rooted in the national resource and cultural endowments, capacity to made investment in education and research, and institutional structure and government support. In the real world situation, the proactive role of public policies are essential to protect and enhance the existing competitive advantages and also to reduce knowledge gap between the advanced and backward countries (World Bank, 1999).

The national economies have been growing in the interdependent world. Therefore, national innovation system is continuously being influenced by the changes occurring in other parts of the world. During the past two decades, the collaborative R&D in pre-competitive research has emerged as a key tool of knowledge generation policy at the national and supranational levels (Roediger-Schluga and Barber, 2006). The dramatic reduction of tariff barriers for international trade, direct foreign investment and cross border flows of finance capital have altered the rules of global management system. With the establishment of World Trade Organization (WTO), the transnational corporations have dramatically influenced the national innovation system and innovation outcomes. On the one hand, the WTO pushed forward the liberalization of trade and capital flows across national boundaries but tightened rules and regulations related to commercial use of intellectual property rights on the other hand (Commission on Intellectual Property Rights, 2002). Why were trade related intellectual property rights changed from public to private rights by the WTO precisely because of the rapid increase in the private sector initiative led R&D expenditure in the industrially advanced countries. The dramatic rise of proportion of private R&D in total R&D in the developed countries essentially reduced public sector R&D as a minor partner during the last quarter of the 20th century (Singh, 2004). Protection was provided by the WTO to the global players of generation of knowledge to reap economies of scale and reduce externalities so that further investment in knowledge can be increased. The monopoly rights in IPRs ensured by the WTO have been examined and put to rigorous tests by the leading experts and found that it may reduce global innovations but surely will not benefit to the less developed countries (Helpman, 1993; and Grossman and Lai, 2004). However, in this era of liberalization and globalization, the developing economies have substantially altered earlier institutional arrangements for national rules and regulations in favour of receiving higher investments both in productive economic activities and innovations. Some of the developing economies are receiving higher flows of investment and research and development flows from developed countries TNCs and others have lagged behind (Singh, 2009).

The fundamental aim of this paper is to investigate global trends in terms of R&D inputs and output measures to establish that how liberalization era, started with the establishment of WTO, have affected the innovation system and economic structure of the developing economies. The evolution of internationalization of R&D and its impact on revealed technological advantage during the recent phase of liberalization is examined with a view to ascertain the process of homogenization or diversity in the national systems of innovation. Furthermore, the historical experience of policy making and role of international institutions and national governments during the liberalization era are examine to draw implications for the science and technology policy and innovative interventions that can generate national capabilities for strengthening national system of innovation in the developing countries.

The paper is organized into six sections. Apart from introductory section one, the theoretical and empirical aspects of the debate on how will global innovations be affected in liberalized regime enacted by the WTO in section two? To ascertain impact of liberalization of innovation regime across countries, the indicators of innovations based on input-output measures have been presented in section three. Fourth section contains the discussion related to internationalization of R&D and revealed technological advantage. Fifth section investigates the role of international agencies to enact rules of the game in an open innovation system and the national governments in terms of enacting innovative interventions in the fast globalising world economy. Policy implications for science and technology development of other developing countries that emerge from the national system of innovations and fast development experience of the successful East Asian countries are presented in the concluding section.

**2. National System of Innovation in Transition**:

Innovations trigger economic growth and structural transformation is widely acclaimed and accepted fact in economic growth literature. Innovations entails organizational as well as changes in the rules of the game. Thus, transition in the national innovation system is the fundamental determinant of long-run economic growth and development. This is being reflected through the changes, which are occurring in the economic structure of an economy as well as in the structure of the innovation system. The history of economic development of the developing and newly industrializing economies shows that national systems of innovation have evolved keeping in view the most pressing requirements of the national economic development. The process of economic growth thus brings in economic transformation and non steady state economic growth. Technology has emerged as a distinct and key factor that determines changes in the long run economic growth and structure of the economy. It needs to be noted here that the innovations are of two types that is radical and incremental (Fagerberg and Verspagen, 2001). Radical innovations open up new opportunities and push the frontiers of knowledge, which dramatically alter the existing economic structure. Incremental innovations not only improve the practices of the existing technologies but are potent factor of diffusion of the radical innovation that engineer structural change in the economic system. However, imitation tends to erode differences in technological competencies across economic activities and over time that reduces differentials and gaps in economic activities. Therefore, radical and incremental innovations are a source of structural transformation and divergence in economic growth and imitation acts as an agent of reducing productivity gaps and initiates the process of convergence. Both the processes of innovations continuously remain in action and the combination of the two actually determines the economic transformation and convergence in the economic system (Fagerberg and Verspagen, 2001). Liberalization era has secured tight intellectual property rights and its implementation will reduce imitative and innovative adaptations. This may significantly affect the future emergence of innovation system in the less developed countries. According to Commission on Intellectual Property Rights (2002), there is an increasing concern that protection of IPRs under the influence of commercial pressures, which insufficiently circumscribed by consideration of public interest and are being extended with a purpose of protection the value of investment than to create or stimulate inventions. It was also apprehended that denying access to developing countries scientists to the protected data related to important diseases or new crops affects the developing countries. This implies that knowledge gaps will continue to rise that will also allows productivity gaps to further increase and cripple the process of productivity convergence.

Changing the structure of production and altering technological trajectories are among the most formidable policy challenge facing NSI, given that when uncertainty and risk are high, the danger that markets will under perform relative to public policy objectives is particularly great (Edquist and Hommen, 2006). However, Lundvall (1992) asserted that NSI would continue to pursue distinctive national trajectories, even under the homogenizing influence of globalization process. It is important to note here that developing countries have been under sustained pressure to increase the levels of intellectual property protection based on standards in developed countries. This harmonization process of IPRs protection has severe consequences for adverse distribution of income for developing countries. According to one estimate, the most developed countries would gain net benefits from WTO regime of IPRs and US alone will gain $ 19 billion annually but the developing countries will incur deficit from the IPRs related transactions (Commission on Intellectual Property Rights, 2002).

It is important to note here that the knowledge generation process in the national system of innovation has undergone a fundamental non-reversible structural change in the developed countries. It is the transition from fundamental research to applied one. This phenomenon has been described as a dual "crowding out". Firms are now increasingly engaged in applied research and do not finance fundamental research either in house or in the institutions of higher learning is one form of crowding out. The other form of crowding out is the near absence of fundamental research from the public laboratories and the university research (Soete, 2006). During the period of liberalization, even in less developed countries the government support to the R&D institutions reduced substantially and asked these institutions to find financing while supplying innovation output to industry (Singh, 2004). Therefore, there was not only reduction of public support and financing to the public institutions, which were mainly contributing to global pool of fundamental knowledge, but orientation of these institutions was changed to applied research. This process set in especially under the WTO regime may reduce global pool of knowledge and hence has a capacity to reduce future scope of innovations because applied knowledge is highly dependent on drawing knowledge from the availability of the fundamental global pool of knowledge (Helpman, 1993; and Grossman and Lai, 2004).

The reduction of barriers on foreign capital in the post WTO regime has dramatically affected the rules and regulations that govern across border flows. The analysis of the Table 1 reveals that the number of countries increased from 43 in 1992 to 63 in 1995 who have introduced regulatory changes from 77 to 112 during the same period.

Table 1: Global Trend of Regulatory Changes Relating to International Investments from 1992-2007

| Items | 1992 | 1995 | 2000 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|
| Number of countries that introduced changes | 43 | 63 | 70 | 92 | 91 | 58 |
| Number of regulatory changes | 77 | 112 | 150 | 203 | 177 | 98 |
| More favorable changes | 77 | 106 | 147 | 162 | 142 | 74 |
| Less favorable changes | 0 | 6 | 3 | 41 | 35 | 24 |

Source: UNCTAD (2008)

The number of countries and changes further increased at a fast rate from 1995 to 2000 and reached at a peak in 2005 when 92 countries introduced 203 changes in the regulations related to international investment. When we make a comparison with highly favourable and favourable, out of 203 regulatory changes 162 were highly favourable. Thereafter the changes introduced with regard to regulations continued and largely more favourable changes with regard to the operation of multinational companies across countries dominated (Table 1). It is significant to note that these changes may have profound effects on the national economies of the developing countries in general and national system of innovations of developing countries in particular. The first and foremost impact of these relaxations provided by the developing countries to attract foreign companies and investment can be ascertained in terms of changing structure of production of the developing countries. The production structure of developing economies substantially changed to follow the production structure observed in the developed countries (Table 2).

The changes occurring in the gross domestic product produced in the three sectors of the economies shows that the global economy generated 69 per cent of the income from the service sector of the economy. It is well known that agriculture sector has lost its importance as a prime sector of the global economy but the industrial sector also losing fast its importance in the production structure of the global economy. This process has been described as deindustrialisation. However, it is well known that the industrially advanced countries have recorded changes in the production structure and dramatically moved towards service oriented and more specifically knowledge generating economies.

Table 2: Sectoral distribution of GDP across Asian Countries 1990 and 2005

| Region/Country | Agriculture | | Industry | | Service | |
|---|---|---|---|---|---|---|
| | 1990 | 2005 | 1990 | 2005 | 1990 | 2005 |
| High Income Countries | 3 | 2 | 32 | 26 | 65 | 72 |
| Middle Income Countries | 16 | 9 | 39 | 38 | 46 | 53 |
| Low Income Countries | 32 | 22 | 26 | 28 | 41 | 50 |
| East Asia and Pacific | 25 | 13 | 40 | 46 | 35 | 41 |
| South Asia | 31 | 19 | 27 | 27 | 43 | 54 |
| Bangladesh | 30 | 21 | 22 | 27 | 48 | 52 |
| Nepal | 52 | 40 | 16 | 23 | 32 | 37 |
| India | 31 | 21 | 28 | 27 | 41 | 52 |
| China | 27 | 13 | 42 | 46 | 31 | 41 |
| Pakistan | 26 | 22 | 25 | 25 | 49 | 53 |
| Sri Lanka | 26 | 18 | 26 | 27 | 48 | 55 |
| Indonesia | 19 | 15 | 39 | 44 | 42 | 41 |
| Philippines | 22 | 14 | 35 | 32 | 44 | 54 |
| Thailand | 13 | 10 | 37 | 44 | 50 | 46 |
| Malaysia | 15 | 10 | 42 | 50 | 43 | 40 |
| South Korea | 09 | 04 | 42 | 41 | 50 | 56 |
| Hong Kong | - | - | 25 | 11 | 74 | 89 |
| Singapore | - | 00 | 38 | 35 | - | 65 |
| World | 06 | 04 | 33 | 28 | 61 | 69 |

Source: World Bank (2006) World Development Indicators 2006, Washington, D.C.: The World Bank.

The developing countries were being characterized as predominantly production oriented. It is worth noting that the opening up of the developing economies has been substantially impacted in terms of changes in the production structure. The production structure of the developing countries turn to be predominantly service oriented with some exception of East Asian countries where industrial sector still generated larger proportion of gross domestic product. However, these economies in the post WTO regime are fast approaching to become predominantly service oriented. It needs to be mentioned here that most of the East Asian countries are following the standard pattern of structural change but most of the developing countries are prematurely becoming service sector oriented (Table 2).

These changes in the production structure of the developing countries can essentially be attributed to the international linkage of these economies. As the developing economies are becoming more open, they are fast becoming service oriented. This is how the developed countries and operation of international investment and trade has played an important role in changing the production structure of the developing countries. The rise of inter-linkage between the developed and developing countries has also substantially altered the emerging national system of innovations from national needs to international needs. It has been moving from more public oriented to private sector oriented and from fundamental to applied. Even the operation of multinational corporations in the developing countries have impacted on domestic firms not to incur in-house R&D expenditure rather depend for technological knowledge on these companies.

The world economy is passing through a worst form of recession triggered with financial meltdown in US and spread over to many developed and developing economies due to its devastating effects on the real productive sectors. According to Wade (2009), the Anglo-American model of liberal capitalism has lost credibility compared with the French model based on national objectives and state-favoured industries and steering markets by the state seems to be the most acceptable norm. He further argued that state should support innovations in the areas of biotech, nanotech, new materials, new transport systems and healthcare. These activities not only will be helpful in the revival of growth process but will also save environment and facilitate lifetime education. This requires reversal of role of global institutions to bring in the agenda of social justice and equity considerations instead of pursuing the commercial interest of developed countries and that too of the commercial organizations. The developing countries must be allowed in enacting and framing Public policies in such a manner, which are suited to the stage of economic development and specific circumstances so that development must result in benefiting the developing countries to reduce technological and productivity gaps across countries and within countries across sectors or classes.

**3. Structure and Trends in Global Innovations**:

The recent phase of globalization has increased interdependence of countries and international flows of trade, technology and finance along with universally applicable IPRs may have substantially increased the openness of the national innovations systems. Therefore, it is instructive to understand the changes that have occurred during the last decade and a half in the national system of innovation in the global economy related to investment pattern in the national systems of innovation. This can be ascertained from the two types of indicators, that is, input and output indicators of innovations. One of the most important input measures that generate innovations is research and development expenditure, which is presented in Table 3. Research and development expenditure in the whole world, which is investment for generation of innovations, as per UNESCO estimates, was 409 billion dollars on purchasing power parity (PPP $) in the year 1990. countries were 811.64 billion PPP dollars, which was nearly 82 per cent (81.64 per cent) of the total global expenditure in the year 2005. This shows that there was a rise in the relative share of developed countries in the total global R&D nearly 3 percentage point within a half decade. Although the total expenditure of the developing countries has increased but the rate of rise was slow that has shifted the relative position of R&D expenditure in favour of developed countries.

An interesting finding worth mentioning here is that the relative share of global R&D expenditure of the North America was 38.16 per cent of the total global R&D in 1990, which marginally declined to 37.21 per cent in 1999-2000. The R&D of North America declined during the decade of 1990s less than one percentage point. But it marginally improved in the first half decade of the 21$^{st}$ century. The lead and dominance of this region in the global R&D expenditure continued during the period of analysis.

Table 3: Structure and Trends of Global Research and Development Expenditure.

| Region/Year | R&D expenditure (billion PPP$) 1990 | R&D expenditure (billion PPP$) 1999/2000. | R&D expediture (billion PPP $) 2005 |
|---|---|---|---|
| World total | 409.8 (100.00) | 755.1 (100.00) | 993.69 (100) |
| Developed Countries | 367.9 (89.77) | 596.7 (79.02) | 811.64 (81.68) |
| Developing countries | 42.0 (10.25) | 158.4 (20.98) | 182.05 (18.32) |
| North America | 156.4 (38.16) | 281.0 (37.21) | 373.02 (37.54) |

Source: UNESCO (2004 and 2008).

The share of developed countries research and development expenditure in the global economy was 89.77 per cent and developing countries were just contributing 10.25 per cent in the year 1990. According to the UNESCO estimates for the year 1999-2000, the total global research and development expenditure increased to 755.1 billion PPP dollars. The developed countries expended 597.7 billion PPP dollars, which was 79.02 per cent of the total global R&D expenditure. The developed countries relative share of global R&D expenditure declined from 89.77 per cent to 79.02 per cent during the period 1990 to 1999-2000. This was a decline of 10.75 percentage points, which is quite substantial during the decade of the 1990s. The rise of R&D expenditure in the newly industrializing countries of Asia on the one hand and decline of East European countries expenditure on the other was the major reason for this dramatic change during the decade of 1990s (Singh, 2007). The analysis of the Table 3 reveals that there was a rise of R&D expenditure in the global economy from 755.1 billion PPP dollars in 1999-2000 to 993.69 billion PPP dollars in 2005. The total R&D expenditure incurred by the developed countries was 811.64 billion PPP dollars, which was nearly 82 per cent (81.64 per cent) of the total global expenditure in the year 2005. This shows that there was a rise in the relative share of developed countries in the total global R&D nearly 3 percentage point within a half decade. Although the total expenditure of the developing countries has been increased but the rate of rise was slow that has shifted the relative position of R&D expenditure in favour of developing countries.

Innovative investment expenditure rise if accompanied with the rise in gross domestic product depicts a real rise in the investment in the knowledge generation activities. Therefore, R&D expenditure-gross domestic product (R&D-GDP) ratio represents innovation investment intensity. This indicator change over the period truly reflects the rise or fall of effort of a particular country in the knowledge generation activities. The R&D-GDP ratio for the period 1991 and 2006 and the sources of finance across OECD and BRICS countries for the year 2006 are presented in Table 4. It is important to note from the analysis of the table 4 that the OECD R&D-GDP ratio has increased slightly from 2.20 in 1991 to 2.26 in 2006. A substantial fall in the R&D-GDP intensity has been recorded in many OECD countries between the period 1991 and 2006. Most prominent among them are UK, Italy, Netherlands, Norway and France. There is also a marginal decline in this ratio for US. A dramatic decline of R&D-GDP ratio has been reported from the East European countries such as Poland, Hungary, Slovak Republic and Czech Republic. But in other OECD countries innovation investment intensities have increased substantially. These countries are Australia, Austria, Belgium, Canada, Denmark, Finland, Iceland, Ireland, New Zealand, Spain, Sweden and Switzerland. Two Asian countries, that is, Japan and South Korea are OECD member countries, where R&D-GDP ratios have sharply increased (Table 4). Germany economy's R&D-GDP ratio has registered a marginal rise between the period 1991 and 2006. However, there are low innovation investment intensity OECD countries, that is, Greece, Portugal and Turkey, which have recorded an increase of R&D expenditure between the period 1991 and 2006. An interesting finding which comes out of the analysis of the structure and pattern of financing of research and development expenditure of the low R&D-GDP ratio OECD countries is that more than fifty per cent research and development expenditure has been done in these countries by the government. But in the high innovation investment intensive OECD countries, more than fifty per cent financing of R&D is being done by the industry. This ratio is 75.45 per cent for Korea, 77 per cent for Japan and 79.72 per cent for Luxembourg.

The business enterprise R&D expenditure shows that for the OECD as a whole nearly 90 per cent expenditure has been incurred by the industry (Table 4). However, there are wide variations across OECD countries so far as the business enterprise R&D

Table 4: Innovation Intensity and R&D Financing Pattern across OECD and BRICS Countries

| Country | % of GDP | | % Financed by 2006 | | % Financed by Business enterprise expenditure 2006 | |
|---|---|---|---|---|---|---|
| | 1991 | 2006 | Govt. | Industry | Govt. | Industry |
| Australia | 1.31 | 1.78 | 40.51 | 52.97 | 4.3 | 93.4 |
| Austria | 1.44 | 2.45 | 36.58 | 46.35 | 6.4 | 67.2 |
| Belgium | 1.62 | 1.83 | 24.65 | 59.68 | 6.5 | 82.5 |
| Canada | 1.60 | 1.94 | 32.68 | 47.97 | 2.7 | 81.6 |
| Czech Republic | 1.90 | 1.54 | 38.97 | 56.91 | 13.6 | 83.7 |
| Denmark | 1.61 | 2.43 | 27.58 | 59.53 | 2.4 | 86 |
| Finland | 2.02 | 3.45 | 25.11 | 66.56 | 3.7 | 89.9 |
| France | 2.33 | 2.11 | 38.39 | 52.24 | 10.1 | 80.8 |
| Germany | 2.47 | 2.53 | 28.38 | 67.57 | 4.5 | 92 |
| Greece | 0.36 | 0.57 | 46.82 | 31.06 | 5.6 | 85.7 |
| Hungary | 1.06 | 1 | 44.77 | 43.3 | 8.4 | 75.6 |
| Iceland | 1.18 | 2.78 | 40.5 | 48 | 2.8 | 84.9 |
| Ireland | 0.93 | 1.32 | 30.13 | 59.26 | 3.9 | 86.5 |
| Italy | 1.23 | 1.09 | 50.68 | 39.66 | 9.7 | 79.2 |
| Japan | 2.76 | 3.39 | 16.18 | 77.07 | 1 | 98.5 |
| Korea | 1.84 | 3.23 | 23.07 | 75.45 | 4.7 | 94.8 |
| Luxembourg | - | 1.47 | 16.61 | 79.72 | 5.2 | 91.7 |
| Mexico | - | 0.5 | 45.34 | 46.49 | 5.7 | 92.6 |
| Netherlands | 1.97 | 1.67 | 36.23 | 51.06 | 3.4 | 81.6 |
| New Zealand | 0.98 | 1.16 | 42.98 | 41.25 | 11.3 | 80.7 |
| Norway | 1.64 | 1.52 | 43.99 | 46.41 | 10.5 | 80.7 |
| Poland | 0.76 | 0.56 | 57.45 | 33.05 | 12.3 | 80.9 |
| Portugal | 0.57 | 0.83 | 55.2 | 36.27 | 4.2 | 91.4 |
| Slovak Republic | 2.13 | 0.49 | 55.56 | 34.96 | 20.8 | 68.2 |
| Spain | 0.81 | 1.2 | 42.49 | 47.07 | 14.4 | 79 |
| Sweden | 2.72 | 3.73 | 23.5 | 65.7 | 4.2 | 87.1 |
| Switzerland | 2.59 | 2.9 | 22.71 | 69.73 | 1.5 | 90.9 |
| Turkey | 0.53 | 0.76 | 48.63 | 46.05 | 8.7 | 90 |
| UK | 2.07 | 1.78 | 31.87 | 45.2 | 7.6 | 69.4 |
| US | 2.71 | 2.62 | 29.34 | 64.89 | 9.3 | 90.7 |
| OECD TOTAL | 2.20(1.87*) | 2.26 | 29.46 | 62.71 | 6.8 | 89.6 |
| Brazil | - | 1.02 | 57.88 | 39.38 | 0.8 | 99.2 |
| China | 0.74 | 1.42 | 24.71 | 69.05 | 4.5 | 91.2 |
| India | 0.79 | 0.71 | 80.81 | 16.11 | - | - |
| Russian Federation | 1.43 | 1.08 | 61.1 | 28.8 | 52 | 35.7 |
| South Africa | 0.84 | 0.92 | 38.19 | 43.87 | 16.2 | 68.3 |

*Denotes EU-15

Source: OECD (2008).

expenditure proportion of government and industry is concerned. But the analysis of the sources of business enterprise R&D expenditure clearly brings out the fact that it is largely done by industrial sector of the OECD economies and governments have been reduced to a junior partner that is why in these countries commercial interest are quite influential in so far as the domestic and international policy making related to protection of IPRs is concerned. It is widely held view that future engines of global economic growth are BRICS countries that is Brazil, Russia, India, China and South Africa. Among the BRICS countries, India is the lowest R&D expenditure incurring country in terms of her R&D-GDP ratio, which is 0.71 per cent in 2006. This ratio for South Africa was 0.92 per cent. Although, both the countries are spending less than one per cent of GDP, but the R&D-GDP ratio has marginally declined in the case of India whereas it increased substantially in the case of South Africa. For Russian Federation the R&D-GDP ratio has declined between the period 1991 and 2006 but remained more than one per cent. China has dramatically improved the innovation intensity investment and was below India's level at 1991 and not only surpassed India but has emerged as the highest R&D expending country among the BRICS countries. The R&D-GDP ratio has increased from 0.74 per cent in 1991 to 1.42 percent in 2006 (Table 4). There are two distinct pattern of source of finance of R&D expenditure that emerged from the analysis of the expenditure pattern of BRICS countries. One, the government is the major or dominant source in terms of financing R&D expenditure in three countries, that is, India, Russian Federation and Brazil. Two, the industry turns out to be the major source of finance of R&D in China and South Africa.

Apart from resource allocations for the development and creation of new knowledge, the researchers engaged in the conception or creation of new knowledge, development of new products and processes are the fundamental and the only dynamic factor input in the national innovation system. The researchers (scientist and engineers) are the professionals, which are working with the availability of investment resources in knowledge generation activities. Therefore, the human resources devoted for knowledge generation in a particular region/country are the most important indicator of the intensity of input measure. The researchers engaged in R&D activities across regions and countries are presented in Table 5. The total number of researchers engaged in the global economy was 5521.4 thousands in the year 2002. It comes out to be 894 per million inhabitants and per researcher R&D expenditure was incurred US $ 150.3 thousands. When one divides the researchers engaged in innovation activities across developed and developing economies, there was high degree of concentration of the researchers engaged in the developed economies. Out of the total researchers engaged in the innovation activities in the global economy, more than 70 per cent were working in knowledge generation and development of new products and processes activities in the developed countries. The developing economies have been engaging just 29 per cent of the total researchers engaged in the global economy. The intensity of researchers, that is, per million inhabitants number of researchers, was 3272.7 in the developed countries in the year 2002. However, this intensity was 374.3 researchers per million inhabitants in the developing countries, that is, more than 8 times low in the developing countries compared than that of the advanced countries. It is heartening to note that the less developed countries had engaged only 0.1 per cent of the global researchers engaged in the national innovation system and researchers' intensity was also very low, that is, 4.1 researcher per million inhabitants. These indicators provided ample evidence of the inequitable national innovation system emerging in the global economy. Continent wise distribution of researchers employed in the innovation activities clearly brings out the fact that Asia as a continent has emerged as the largest in terms of the proportion of the researchers engaged in the global economy. The share of researchers employed in Asia was 36.8 per cent of the global economy and emerged number one continent just ahead of Europe, which has engaged 33.4 per cent of the total researchers (Table 5).

So far as the proportion of researchers engaged in R&D activities are concerned, North America comes at number three in the global economy. According to the intensity indicator of researchers, the North America engaged 4279.5 researchers per million inhabitants. This is the highest number of researchers that provides the prime position, that is, number one rank in the global economy to North America continent. The Europe turns out to be number two in the global economy according to the intensity of researchers as an indicator of research intensity. The gap in terms of intensity of researchers between North American and Europe was very large. It is important to note that this gap is highest between North America and Asia, that is, four times.

Table 5: Researchers Engaged in Innovations in Developed and Developing Countries.

| Region/Year | Researchers (Thousands) | Per cent of World researchers | Researchers per million inhabitants | GERD per researcher (US $ thousands) |
|---|---|---|---|---|
| World total | 5521.4 | 100.00 | 894.0 | 150.3 |
| Developed Countries | 3911.1 | 70.8 | 3272.7 | 165.1 |
| Developing countries | 1607.2 | 29.1 | 374.3 | 114.3 |
| Less Developed countries | 3.1 | 0.1 | 4.1 | 153.7 |
| North America | 1368.5 | 24.8 | 4279.5 | 224.5 |
| Latin America & Caribbean | 138.4 | 2.5 | 261.2 | 156.5 |
| Africa | 60.9 | 1.1 | 73.2 | 76.2 |
| Asia | 2034.0 | 36.8 | 554.6 | 128.5 |
| Europe | 1843.4 | 33.4 | 2318.8 | 122.7 |
| Brazil | 54.9 | 1.0 | 314.9 | 238.0 |
| China | 810.5 | 14.7 | 633.0 | 88.8 |
| India | 117.5 | 2.1 | 112.1 | 176.8 |
| Russian Federation | 491.9 | 8.9 | 3414.6 | 30.0 |
| South Africa | 8.7 | 0.2 | 192.0 | 357.6 |
| UK | 157.7 | 2.9 | 2661.9 | 184.2 |
| USA | 1261.2 | 22.8 | 4373.7 | 230.0 |

Source: UNESCO (2005a) UNESCO Science Report, UNESCO

Thus, Asia turns out to be number third in terms of intensity of researchers per million inhabitants which is still very low. Even the expenditure incurred per researcher is highest in North America followed with substantial gap in Europe and Asia. The intensity of researcher shows that Latin American and Caribbean countries were ranked number four and Africa turns out to be lowest ranked according to intensity and the proportion of researchers as an indicator of innovations among the five regions of the global economy.

Among the BRICS countries, China and Russian Federation were quite ahead according to intensity of researchers engaged in innovation activities. However, India, Brazil and South Africa are the three BRICS countries having very low intensity of researchers engaged in knowledge generation activities.

The resources incurred for innovations and capability building show results not only in terms of developing a system of innovations but also nurture economic agents of production to participate, learn to use and develop new knowledge and products. Therefore, there is a positive relationship between resources expended in new knowledge creation and innovation output, that is, contribution of a national economy in producing scientific and technical journal articles, patents, royalty payments received and internationally traded high-tech goods and services. The contribution of scientific and technical journal articles during the period 1995-2005 across the regions of global economy are presented in Table 6. During the period 1995-2005, the scientific and technical journal articles in the global economy increased from 436951 to 708086. The rate of growth of scientific and technical journal articles turns out to be 4.5 per cent per annum during the period of analysis. The high-income countries contributed 379529 scientific and technical journal articles in the year 1995 which turns out to be 86.86 per cent of the total number of scientific and technical journal articles of the global economy. There was a significant increase in the contribution of high income countries to the scientific and technical journal articles over time and published 578656 number of scientific and technical journal articles in 2005. The per annum rate of growth of scientific and technical journal articles of high-income countries was 6.21 per cent. This rise in the growth rate was higher than that of the rise of rate of growth of scientific and technical journal articles in the world as a whole. However, the global share of scientific and technical journal articles of high-income countries declined from 86.86 per cent to 81.72 per cent during the period 1995-2005. This decline was more than 5 percentage point. On the other hand low-income countries contribution in scientific and technical journal articles in absolute numbers have increased from 14646 to 16711 between the period 1995 and 2005 and the rate of growth turns out to be 1.9 per cent per annum. But the relative contribution of the low-income countries declined from 3.35 per cent to 2.36 per cent during the period 1995 to 2005. The East Asia and Pacific countries substantially raised their contribution to the scientific and technical journal articles during the period 1995-2005. The relative share increased from 2.1 per cent in the total number of scientific and technical journal articles in the world as a whole in 1995 to 6.22 percent in the year 2006. The scientific and technical journal articles increased at a rate 25.15 per cent per annum of the East Asia and Pacific countries, which was the highest among the regions classified in Table 6.

Table 6: Scientific and Technical Journal Articles in the Global Economy

| Regions/ Year | 1995 | 1997 | 1998 | 1999 | 2001 | 2003 | 2005 |
|---|---|---|---|---|---|---|---|
| Low income countries | 14646 (03.35) | 13572 (02.65) | 13565 (02.65) | 14376 (02.72) | 13147 (02.03) | 14,929 (02.14) | 16,711 (02.36) |
| Middle income countries | 42776 (09.79) | 61762 | 61733 | 62409 | 84507 | 100,288 | 112,719 (15.91) |
| Lower middle income Countries | 23775 (05.44) | 35148 (06.86) | 32967 06.43) | 39216 (07.42) | 61791 (09.02) | 49,969 (07.16) | 53,423 (07.54) |
| Upper middle income Countries | 19001 | 26614 | 28767 | 23193 | 22716 | 50,319 | 59,296 |
| Low & middle income Countries | 57422 | 75334 | 75298 | 76785 | 97654 | 115,217 | 129,430 |
| East Asia & Pacific countries | 9164 (02.10) | 14817 (02.89) | 14817 (02.89) | 13055 (02.47) | 22722 (03.50) | 31,351 (04.49) | 44,064 (06.22) |
| Europe & Central Asia | 30483 | 34905 | 34905 | 34679 | 39077 | 42,695 | 39,975 |
| Latin America & Caribbean | 6449 | 10093 | 10075 | 12033 | 16045 | 18,588 | 20,045 |
| Middle East & North African countries | 1136 | 3123 | 3106 | 3637 | 4699 | 5,358 | 6,354 |
| South Asia | 7851 | 8896 | 8896 | 9769 | 11611 | 13,487 | 15,429 |
| Sub-Saharan Africa | 239 | 3499 | 3499 | 3612 | 3500 | 3,738 | 3,563 |
| High income countries | 379529 (86.86) | 437303 (85.30) | 437339 (85.31) | 451842 (85.47) | 550846 (84.94) | 582,180 (83.48) | 578,656 (81.72) |
| Europe (EMU) | 98365 | 115641 | 117764 | 122077 | 148169 | 156,184 | 158,066 |
| World | 436951 | 512637 | 512637 | 528627 | 648500 | 697,397 | 708,086 |

Note: Figures in parentheses are percentages.
Source: World Bank, **World Development Indicators**, Various Issues.

The second highest growth rate recorded by the upper middle-income countries, that is, 17.65 per cent per annum during the period under analysis. The relative share also increased from 4.37 per cent in 1995 to 8.37 percent in the world as a whole during the period 1995-2005. The Latin American and Caribbean countries had very low base in terms of their contribution to scientific and technical journal articles was concerned but the rate of growth was 17.59 per cent during the period 1995-2005. The relative share of the Latin American and Caribbean countries increased from 1.5 per cent to 2.8 per cent in 1995 to 2005. However, their contribution in terms of adding knowledge to global pool of knowledge through scientific and technical journal articles remained quite low. This is lower than even that of South Asian countries. The contribution of middle-income countries was 9.79 per cent in 1995, which was increased to 15.91 per cent in 2005, to the total global scientific and technical journal articles. The growth rate per annum turns out to be 14.85 per cent. The overall conclusion, which emerged from the analysis of the Table 6, is that although high income countries contribution to scientific and technical journal articles has declined but the relative share remained higher than 81 per cent. This clearly shows that there is high degree of concentration of output indicator of research and development in the high-income countries. The research collaborations that result into the publication of joint authorship scientific and technical journal articles remained concentrated (more than 70 per cent) among the high-income countries (UNESCO, 2005b).

Table 7: Global Trends of Patent Applications Filed by the Residents and Non-Residents

| Region/ Patents | Residents 1997 | Non-Residents 1997 | Residents 2004 | Non-Residents 2004 |
|---|---|---|---|---|
| Low income countries | 23772 (02.98) | 648006 (17.99) | 7259 (00.83) | 12067 (02.54) |
| Middle income countries | 126138 | 817452 | 105144 | 120688 |
| Lower middle income countries | 27027 | 449771 | 76157 | 90921 |
| Upper middle income countries | 99111 | 367681 | 28987 | 29767 |
| Low & middle income countries | 149910 | 1465458 | 112403 | 132755 |
| East Asia & Pacific | 106342 (13.33) | 184288 (05.11) | 66112 (07.58) | 70866 (14.96) |
| Europe & Central Asia | 31081 | 685716 | 34767 | 19989 |
| Latin America & Caribbean | 1708 | 175004 | 4498 | 29255 |
| Middle East & North Africa | 509 | 1207 | 215 | 871 |
| South Asia | 10236 | 26322 | 6765 | 11752 |
| Sub-Saharan Africa | 38 | 392921 | 16 | 22 |
| High income countries | 648093 (81.21) | 2137327 (59.32) | 759875 (87.11) | 341015 (71.98) |
| Europe (EMU) | 101037 | 1086902 | 72974 | 15757 |
| World | 798003 | 3602785 | 872278 | 473770 |

Note: Figures in parentheses are percentages.
Source: As above in Table 6.

Another important output indicator of innovation is the patent application filed in an economy by the residents and the non-residents, which are provided for the years 1997 and 2004 in the Table 7. The analysis of the table clearly brings out the fact that there was a substantial rise in the number of applications filed in the high-income countries both by the residents and no-residents between the period 1997 and 2004. The relative shares of application filed by the residents and the non-residents in the high income group of countries have increased from 81.21 per cent and 59.32 per cent respectively in the year 1997 to 87.11 per cent and 71.98 per cent respectively in 2004. This is ample evidence that allow us to conclude that there is a tendency of concentration of innovation output in the high-income countries. But the share of low-income countries declined over the same period so far as patent applications filed both by the residents and non-residents are concerned. The share of patent applications filed by the low-income countries has declined from 2.98 per cent in 1997 to less than one per cent in 2004. Again during the recent phase of globalization, the concentration of output indicators of innovation provided evidence enough to conclude that there is high degree of inequitable distribution in new knowledge generated across countries and regions.

Technology related transactions across countries and regions result into royalty and license fee receipts and payments. This indicator shows that how technology generating countries and regions gains from providing consultancy, turn key projects and sale and services. The analysis of royalty and license fee receipts and payments reveals that there is high degree of concentration of technology transactions in the high-income countries of the world (Table 8).

In the whole world, there were US $ 64334 million royalty receipts in the year 1998 which were increased to US $ 135278 million in the year 2006. During this period, the royalty and license fee receipts increased at 8.48 per cent per annum in the whole world. However, the royalty payments increased from US $ 61114 million to US $ 148518 million from 1998 to 2006 and the rate of growth turns out to be 9.8 per cent per annum. The share of royalty and license fee receipts of the high-income countries was 98 per cent in the year 1998 which marginally declined to 97 per cent in the year 2006. Obviously, these countries have been doing large proportion of the R&D expenditure of the global economy. But the share of royalty and license fee receipts is much higher than the total share of global expenditure incurred by these countries.

Table 8: Trends in Royalty and License Fee Receipts, Payments and High-Tech Exports in the Global Economy.

| Regions/ Year | Royalty & license fees receipts million $ 1998 | Royalty & license fees payments million $ 1998 | Gap of Receipt and Payments million $ 1998 | Royalty & license fees receipts million $ 2006 | Royalty & license fees payments million $ 2006 | Gap of Receipt and Payments million $ 2006 | High-Tech exports as per cent of manufacture exports 1998 | High-Tech exports as per cent of manufacture exports 2006 |
|---|---|---|---|---|---|---|---|---|
| Low income countries | 106 | 688 | -582 | 334 | 1,163 | -829 | 13 | 06 |
| Middle income countries | 1177 | 6703 | -5526 | 3,743 | 22,719 | -18976 | 20 | 20 |
| Lower middle income countries | 395 | 1688 | -1293 | 2,154 | 11,140 | -8986 | 17 | 24 |
| Upper middle income countries | 781 | 5015 | -4234 | 1,589 | 11,579 | -9990 | 20 | 16 |
| Low & middle income countries | 1283 | 7391 | -6108 | 4,077 | 23,882 | -19805 | 18 | 20 |
| East Asia & Pacific | 330 | 3374 | -3044 | 297 | 10,959 | -10662 | 28 | 33 |
| Europe & Central Asia | 176 | 623 | -447 | 1,129 | 5,998 | -4869 | 09 | 09 |
| Latin America & Caribbean | 583 | 2350 | -1767 | 753 | 4,146 | -3393 | 12 | 12 |
| Middle East & North Africa | 73 | 566 | -493 | 306 | 247 | 59 | 01 | 05 |
| South Asia | 19 | 206 | -187 | 175 | 1,060 | -885 | 04 | 04 |
| Sub-Saharan Africa | 102 | 273 | -171 | 1,417 | 1,471 | -54 | - | - |
| High income countries | 63051 | 53723 | 9328 | 131,201 | 124,636 | 6565 | 33 | 21 |
| Europe (EMU) | 9808 | 22443 | -12635 | 23,049 | 44,309 | -21260 | 15 | 16 |
| World | 64334 | 61114 | 3220 | 135,278 | 148,518 | -13240 | 22 | 21 |

Source: As in Table 6.

It is significant to note that the share of royalty and license fee receipts of the low income countries was just 0.16 in the year 1998 and it marginally improve to 0.25 in the year 2006. This shows the high degree of inequality in terms of technology generation and participation of the low-income countries in the international technology related transactions. Somewhat similar trends are found in the royalty and license fee payments. The analysis of the Table 8 reveals the fact that high-income countries have net positive receipts from the international transaction of royalty and license fee payments and receipts. But most of the regions made higher payments in terms of royalty and license fee compared with the receipts. Therefore, the gap in the receipts and payments from the royalty and license fee was quite large. This clearly shows the high dependence of the developing countries for technology import from the developed countries disproportion to the innovation investment made and royalty and license fee received.

It is important to note from the analysis of the high-tech exports that are emerging from high income and low-income countries clearly showed a declining trend (table 8). This shows that industrial activities are moving from the high-income countries to other developing countries. The low-income countries could not able to receive either foreign direct investment or high-tech industries. The East Asia and Pacific countries and lower middle-income countries increased substantially the proportion of high-tech trade in the total manufacturing trade. The rise of high-tech trade in both the group of countries has been attributed essential to two factors. One, the operation of multinational corporations in these countries usually follow the practice of inter and intra-industry trade and therefore, the high-tech trade originating from developing countries may actually belong to multinational corporations manufactured goods in the developing countries (Amable, 2000 and Urata, 2001). Two, the innovation system has generated substantial innovation capabilities in the East Asian countries that have led to the rise in high-tech trade from these countries.

**4. Internationalization of R&D and Revealed Technological Advantage**:

The input-output indicators of innovations, during the recent phase of globalization, reveal that global innovations remained highly concentrated and centralized in the advanced countries. The dramatic transformation of national system of innovation across developed and developing economies in terms of shift of innovation generation activities from public to private sector has occurred. The government role seems to have been more of supportive and demand driven. The transnational corporations emerged as the dominant players in the global innovative activities. According to Reddy (2005), the evolution of TNCs R&D internationalization can be divided into four distinct phases. During the first phase, that is, the 1960's, the offshore R&D performed by TNC's was mainly through technology-transfer units and technical problem solving to reduce costs rather than sending R&D missions from headquarters. Second phase of internationalization of R&D by the TNCs (during the 1970's) aimed at to improve the local market share abroad through acquisition of companies and R&D was mainly adaptive in nature used for reverse engineering. The third phase of globalization of R&D in the 1980s marked the higher order R&D while establishing inter-organizational collaborations such as regional technology, global technology and corporate technology units with a view to cater to increasingly convergence of consumer preferences. This led to the rise in science and technology content in the new products, which forced TNCs to invest in R&D to remain competitive as well as legitimize the operation of TNCs abroad. The rising cost of researchers in the R&D bases at TNCs headquarters in advanced countries triggered fourth wave of R&D location abroad during the 1990s. The major aim of internationalization of R&D is to find highly developed science and technology base as well as right kind of highly skilled scientists and engineers available at low cost. There is growing tendency of the TNCs to disperse R&D bases from the headquarters to the select preferred locations in the very recent phase of globalization due mainly to the universally applicable IPRs regime. China and India were able to receive 885 R&D oriented Greenfield projects during the period 2002-2004. By the end of 2004, more than 700 foreign affiliate R&D centres had been started operations in China and more than100 TNCs had established R&D facilities in India. The choice of location of R&D bases by the TNCs have been based on the existence of strong or substantially developed national systems of innovation (UNCTAD, 2005). The leading global players of knowledge activities have recognized the innovative capability of the Asian countries and revealed in a recent UNCTAD survey their preference to locate R&D centers in Asian countries. Foreign affiliate R&D centers have been growing at a fast pace in the Asian countries. Apart from China and India, Singapore is now hosting more than hundred foreign affiliate R&D centers. China, India and Singapore have a very high degree of incidence of establishing foreign affiliate R&D centers up to 2004. The situation assessment survey has also revealed that the leading TNCs will prefer to locate R&D centers in most of the Asian countries (Table 9). China and India have emerged undisputed sites for location of foreign R&D centers between 2005 and 2009 and the 61.8 per cent of the TNCs accorded preference to China and 29.4 per cent revealed choice for

Table 9: Indicators of foreign firm innovation investment destinations

| Country | Current foreign R&D location of TNCs 2004 (per cent) | Prospective R&D location of TNCs 2005-2009 |
|---|---|---|
| China | 35.3<br>(3) | 61.8<br>(1) |
| India | 25.0<br>(6) | 29.4<br>(3) |
| Singapore | 17.6<br>(9) | 4.4<br>(11) |
| Taiwan | 5.9<br>(23) | 4.4<br>(12) |
| Malaysia | - | 2.9<br>(15) |
| South Korea | 4.4<br>(26) | 2.9<br>(16) |
| Thailand | 4.4<br>(27) | 2.9<br>(17) |

Source: UNCTAD (2005).

India among the firms surveyed in 2004 by UNCTAD. Their respective global ranks are first and third. Other important Asian countries, which have been highly rated as preferred location for R&D centers by global knowledge players are Singapore (rank 11), Taiwan (rank 12), Malaysia (rank 15), South Korea (rank 16) and Thailand (rank 17) (Table 5). This is an ample proof of a well-developed innovative infrastructure facilities and conducing innovation institutional arrangements along with highly skilled innovative and low cost human capital.

The globalization of R&D was also emerged from the concern to maintain technological competitiveness of the European high-tech industry. The European Commission in the year 1982 started Framework Programme with a view to develop networking among firms, research organizations and universities and stimulate transnational linkage for locating opportunities and needs beyond their home markets.

Table 10:Revealed Technology Advantages across Industries and Countries (2000-05)

| Field of Technology | No. of spl | Code of Country |
|---|---|---|
| Electrical machinery, apparatus, energy | 4 | KOR, JPN, HKG, AUT |
| Audio-visual technology | 5 | JPN, HKG, NLD, KOR, SGP |
| Telecommunications | 10 | CAN, CHN, FRA, HKG, ISR, JPN, NDR, KOR, SGP, SWE |
| Digital communication | 10 | CAN, CHN, FIN, FRA, ISR, NLD, KOR, SGP, SWE, USA |
| Basic communication processes | 8 | FIN, IND, JPN, NLD, KOR, SGP, SWE, USA |
| Computer technology | 7 | FIN, ISR, JPN, NLD, KOR, SGP, USA |
| IT methods for management | 5 | AUS, IRL, JPN, SGP, USA |
| Semiconductors | 3 | JPN, KOR, SGP, |
| Optics | 4 | JPN, NLD, KOR, SGP |
| Measurement | 11 | CAN, DEU, ISR, JPN, NOR, POL, RUS, SGP, SWZ, UKR, GBR |
| Analysis of biological materials | 20 | AUS, AUT, BEL, CAN, DNK, FRA, DEU, IRL, ISR, NZL, NOR, POL, RUS, SGP, ESP, SWE, SWZ, UKR, GBR, USA |
| Control | 11 | AUS, BRA, DEU, IRL, JPN, NOR, POL, SGP, ESP, GBR, USA |
| Medical technology | 21 | AUS, BEL, BRA, CAN, CHN, DNK, FRA, DEU, IND, IRL, ISR, ITA, NLD, NOR, RUS, ESP, SWE, SWZ, UKR, GBR, USA |
| Organic fine chemistry | 16 | BEL, CHN, DNK, FRA, DEU, IND, IRL, ISR, ITA, NLD, POL, ESP, SWE, SWZ, GBR, USA |
| Biotechnology | 20 | AUS, AUT, BEL, CAN, CHN, DNK, FRA, IND, IRL, ISR, NLD, NZL, NOR, RUS, SGB, ESP, SWE, SWZ, GBR, USA |
| Pharmaceuticals | 21 | AUS, AUT, BEL, CAN, CHN, DNK, FRA, DEU, IRL, ISR, NZL, NOR, RUS, ESP, SWE, SWZ, UKR, GBR, USA |
| Macromolecular chemistry, polymers | 8 | BEL, CHN, FRA, DEU, ITA, JPN, NLD, SWZ |
| Food chemistry | 17 | AUS, BEL, BRA, CHN, DNK, IRL, ISR, ITA, NLD, NZL, NOR, POL, KOR, RUS, ESP, SWZ, UKR |
| Basic materials chemistry | 14 | BEL, BRA, CHN, DNK, DEU, IND, NLD, NOR, POL, RUS, SWZ, UKR, GBR, USA |
| Materials, metallurgy | 14 | AUS, AUT, BEL, BRA, CHN, FIN, FRA, DEU, IND, JPN, NOR, POL, RUS, UKR |
| Surface technology, coating | 5 | BEL, DEU, JPN, NOR, USA |
| Micro-structural and nana-technology | 7 | AUS, CHN, FRA, DEU, KOR, SGB, USA |
| Chemical engineering | 23 | AUS, AUT, BEL, BRA, CAN, CHN, DNK, FIN, FRA, DEU, IND, IRL, ITA, NLD, NZL, NOR, POL, RUS, ESP, SWZ, UKR, GBR, USA |
| Environmental technology | 16 | AUS, AUT, BRA, CAN, CHN, FIN, FRA, DEU, HKG, JPN, NOR, POL, KOR, RUS, ESP, UKR |
| Handling | 18 | AUS, AUT, BEL, BRA, DNK, FIN, FRA, DEU, HKG, IRL, JPN, NLD, NZL, NOR, POL, ESP, SWZ, GBR |
| Machine tools | 16 | AUT, BRA, CAN, FIN, DEU, HKG, ISR, ITA, NZL, POL, RUS, SGP, ESP, SWE, SWZ, UKR |
| Engines, pumps, turbines | 12 | AUT, BRA, CAN, DNK, FRA, DEU, ITA, JPN, NOR, POL, RUS, UKR |
| Textile and paper machines | 8 | AUS, AUT, BEL, FIN, DEU, ITA, JPN, SWZ |
| Other special machines | 19 | AUS, AUT, BEL, BRA, CAN, DNK, FRA, DEU, IRL, ISR, ITA, NLD, NZL, NOR, POL, RUS, ESP, SWZ, UKR |
| Thermal processes and apparatus | 15 | AUT, BRA, CHN, DNK, FIN, DEW, HKG, ITA, JPN, NOR, POL, KOR, RUS, ESP, UKR |
| Mechanical elements | 15 | AUT, BRA, DNK, FRA, DEU, ITA, JPN, NZL, NOR, POL, RUS, ESP, SWE, UKR, GBR |
| Transport | 13 | AUT, BRA, CAN, FRA, DEU, ITA, JPN, NOR, POL, KOR, RUS, ESP, SWE |
| Furniture, games | 14 | AUS, AUT, BRA, CAN, HKG, IRL, ITA, JPN, NZL, NOR, POL, KOR, ESP, GBR |
| Other consumer goods | 15 | AUS, AUT, BEL, BRA, CAN, CHN, FRA, HKG, IRL, ITA, NZL, POL, KOR, ESP, GBR |
| Civil engineering | 21 | AUS, AUT, BEL, BRA, CAN, CHN, DNK, FRA, DEU, IRL, ITA, NLD, NZL, NOR, POL, KOR, RUS, ESP, SWE, UKR, GBR |

SOURCE: WIPO Statistics Database, July 2008.

During the period 1984 to 2002, there were five Framework Programmes initiated 43,317 new projects involving 31,345 multiple partners and 42,020 and 49,855 organizations and sub entities respectively (Roediger-Schluga and Barber, 2006). It is instructive to note that the European Commission Framework Programme remained quite stable and operational policy tool for catering to the need in search of high-tech industrial competitiveness despite the changes in the governance rules. The rise in the cost of frontier areas of research has forced even the TNCs to cooperate to establish joint R&D projects results into specializations in similar kind of new products and competitive advantage in the fast globalization of the operation of TNCs.

The patterns of revealed technological advantage across industries and countries are presented in Table 10. The revealed technological advantage is measured from patenting activity occurring during the period 2000-2005 that shows the field of technological specialization of a particular country in a particular product. The analysis of the revealed technological advantage brings out the fact that in one technology field, there are numerous countries that are possessing similar technological specialization. In the chemical engineering industry, there were as many as 23 countries showed technological specialization as revealed by the patenting activity. The pharmaceutical, civil engineering and medical technological fields show that there are 21 numbers of countries in each group possessed revealed technological advantages.

It is important to note that countries that specialized in the field of engineering, pharmaceutical and medical technologies are mainly the industrially advanced countries and the BRICS countries. Twenty countries are specializing in the technological fields of biological materials and biotechnology. The analysis of the revealed technological advantage presented in Table 10 shows that large number of countries was specializing in the same field of technologies. However, there are a very few technological field such as semiconductors where only three countries, that is, Japan, Korea and Singapore were exclusively specializing. The analysis of revealed technological advantage during the period of fast globalization shows that there seems to be high degree of concentration of specialization in the similar fields of technological specializations. This may provide empirical evidence in favour of inter and intra-industry theory of international trade. This evidence of convergence of technological specializations also shows that globalization may have effected diversity in technological trajectories.

The question of convergence of specialization across countries in the same field poses a formidable challenge to the national system of innovation during the liberalization phase for creating diversity. Even the operation of TNCs in the Asian countries and also R&D location remained highly concentrated in the field of ICT (UNCTAD, 2005). To through light on the question of whether similarity or diversity is occurring in the technological trajectories in the recent phase of globalization has put to empirical verification by Edquist and Hommen (2006). The authors have shown that revealed technological advantage were quite diverse even in the same field of technological specialization while selecting ten countries representing the Europe and the East Asia. Furthermore, it is argued by the authors on the basis of empirical evidence that national innovation system in these countries have not been converged rather have established distinctive role within an increasingly differentiated international division of labour. The East Asian countries have been able to provide institutional support to economic agents of production while extending tax subsidies, providing highly skilled manpower and network of institutional arrangements that allowed these countries to build capabilities for achieving distinctive revealed technological advantages (Singh, 2009).

## 5. Open National System of Innovation and Role of Public Policy:

National system of innovation has been evolved in the developed countries without external intervention and political pressures. Competitive edge of developed economies and of industries has been achieved with substantive public support both direct and indirect. This does not mean that developed countries have not learned from the experience of each other's during the evolution and development of national innovation system. Firms chosen to invest in other developed countries as well as formulated joint ventures to draw on the best practices of others are an ample proof of learning from each other's. Therefore, the national innovation systems have remained quite open and learning took place mainly under the framework of national technology policy.

Economic growth and competitive advantage of national economies in the post world war period remained highly dependent on public support policies (Stern, 2004). Economic agents of production have been nurtured through the support of right kind of economic incentives and institutional arrangements. Innovativeness of the economic agents of production in a national economy thus has remained also highly dependent on technology policy instruments and institutional arrangements (Yusuf, 2003). It has been widely acknowledged and recognized that the leading developed countries and industries, which are adding to the global pool of knowledge through novel innovations and maintaining competitive edge, are highly dependent on well enacted public support system in terms of instruments and institutions (Jaumotte and Pain, 2005).

On other hand, East Asian economies surged ahead in transformation process and succeeded in industrialising their economies as well as building innovation capabilities during the last quarter of the twentieth century. National innovation system is still at its stage of infancy. South Asian countries are striving to put in place the national system of innovation, which allowed its firms to be productive and competitive. However, openness in trade based on rules and regulations framed by global governance institutions have allowed in securing monopoly rights to firms, which have gained competitive edge from their respective national systems of innovation. The intellectual property rights enacted and implemented by World Trade Organisation has been increasingly being questioned both by the academic economists and governments as well as some global institutions. An interesting contribution in this regard is by the World Development Report of the World Bank 1998/1999. This report clearly identified the role of the government in developing countries to develop the capabilities to generate knowledge at home along with providing help to domestic agents of production to take advantage of the large global stock of knowledge. It is significant to note here that the United Nations Development Prorgramme (UNDP, 2001) has gone much ahead in terms of identifying the knowledge gaps existing between developed and developing countries and articulated the arguments against the strict intellectual property rights regime enacted and implemented by the World Trade Organization (WTO). Furthermore, the UNDP has not only suggested innovative and fundamental role of the governments of the developing countries in generating capabilities that matter for knowledge development but also identified knowledge as a global public good and role of international community in reducing the knowledge gaps (UNDP, 2001; and Stiglitz, 1999).

Apart from making suitable public innovation policies to strengthen national innovation systems, the government of developing countries should also strive hard to seek cooperation among themselves as well as of the international institutions and agencies to negotiate in the WTO framework. Specifically, the negotiation should be with regard to TNCs operation in their markets, for doing similar innovative investment as has been done in the home countries. It should also assess losses of domestic firms and seek compensation for using it to create innovative capabilities to strengthen innovative infrastructure at home.

**6. Conclusions and Policy Implications**:

The recent phase of globalization has dramatically reduced tariff barriers, increased flows of trade, technology and finance capital substantially. The rules and regulations governing transnational corporations have been altered to facilitate their operation across national boundaries. Even tax subsidies have been provided to attract foreign direct investment in the developing countries. All these developments have amazingly altered the development path of the developing countries from more domestic policy oriented to internationally policy driven and highly market oriented. This has led to drastically alter the economic structure of the developing economies skipping the stage of industrialization to become prematurely service sector oriented except the newly industrializing East Asian countries such as China, Malaysia and South Korea. The national innovation system has been undergoing an important structural change from predominantly public sector funded to private sector financed. The other structural change during the fast pace of globalization in the national system of innovation has occurred from fundamental research to applied and commercial oriented research. The gap of productivity and innovations remained rather substantial across countries. Global innovations in terms of input efforts and outcomes remained highly concentrated in the developed countries. There has been some evidence of reduction in concentration of innovation investment in the developed economies but the concentration and centralization was increased so far as output indicators of innovations are concerned. East Asian economies have been able not only to reduce the productivity gaps, but also have substantially contributed to reduce knowledge gaps. The growing transnational corporate R&D also remained concentrated in few activities and in a few countries. The internationalization of transnational corporations' R&D remained highly conditioned on the availability of low cost highly skilled human capital and well-developed scientific infrastructure in the developing economies. The increasing influence and operation of the TNCs in the developing economies to some extent have homogenized revealed technological advantages. This has put before the open national innovation system a formidable challenge for creating diversity and specializations across developing economies. The low-income countries remain unable to raise innovation investment intensity and even TNCs have also bypassed so far as location of R&D in these countries is concerned.

Therefore, there is urgent need to enact rules and regulations by the global institutional system to make mandatory for the TNCs to participate and develop innovation capability of the low-income countries. It is thus suggested that the international institutions when enact rules and regulations related to innovation protection and governance must keep space for public policy to allow developing countries to change their destiny. Since the profitability from protection of intellectual property rights of TNCs have dramatically improved therefore some minimum proportion of profits must be transferred for developing national innovation system in the developing countries. The over commercial orientation of the knowledge need not be allowed to reduce emphasis on the fundamental knowledge creation because fundamental knowledge generation ultimately feeds to the commercial exploitation of the knowledge. Global pool of knowledge should be strengthened while restoring faith in the public institutions and liberal financing for such long range and welfare oriented fundamental Research and Development in science and technology.

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