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Globalization of R&D and open innovation: linkages of foreign R&D centers in India

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Abstract

In the new form of Globalization of R&D, Multinational (MNEs) firms have established their R&D units in emerging Asian countries, particularly in India and China. In the 1980s MNEs located their R&D units in their country of origin and were very reluctant to go offshore beyond triad (USA, Western Europe and Japan). However, in the last decade there is a growing trend of MNEs going emerging markets such as India and China. Beside this, sourcing knowledge from globally dispersed knowledge hubs is also one of the major motives of this emerging trend. These foreign R&D centers have developed linkages with the other actors of the host economy to build their assets. This study has investigated the linkage patterns of foreign firms in India from an in-house developed database. The ICT sector is considered as a test case to investigate the linkages of foreign firms with the Indian entities. The study observed that most of the foreign firms are collaborating with the other foreign firms located in India. Next to the foreign firms, Indian firms are preferable compared to university or government research institutes. It shows that industry-academia linkages are quite weak in India. Foreign firms' embededness with the local innovation system is only by linking with the local firms. Although, India has very strong government research laboratories, these are not playing important role in collaborating with the foreign firms. From the policy perspective, industry - academia linkages needs to be strengthened. MNEs enter markets such as India not only for potential markets and 'cheap' skilled human resources but also for knowledge and technology base emerging in the knowledge hubs of these countries. Also, most of the collaboration happens in peripheral (joint development) rather than core domain (joint R&D). Many of the firms are going for 'Open Innovation' mode to build up their assets in India.

Keywords: Globalization of R&D; Linkages; Foreign R&D; Multinational; Open innovation

Background

The term "globalization" has attracted attention of a wide range of disciplines form scholars of advanced as well as developing and emerging economies. In economics and international trade, the process of globalization assumed a good deal of significance through the operation of multinational enterprises (MNEs). The role of MNEs in the era of globalization and the trends of FDI, particularly in Research and Development (R&D) via opening up of MNEs' R&D centres in developing and

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emerging economies are of major research concern today. There are many different actors in globalization of innovation process. However, MNEs have the central role in it because of their multifaceted role in more general process of globalization of innovation (Narula & Zanfei, 2005). Archibugi & Pietrobelli (2003) identified three of types of globalization of technology namely: *international exploitation of nationally produced technology; the global generation of innovation; global technological collaborations.* Enterprises, especially large MNEs, may generate innovations following all these three procedures. However, in recent years, the globalization of innovation comes up with a new face with the growth and spread of the MNEs and FDI beyond the national borders. A new dimension has emerged with the present wave of globalization, particularly since the 1990s is that the MNEs from developed countries are establishing their R&D units in developing countries particularly in India and China (World Investment Report 2005; Krishna et al., 2012).

With the growing pace of globalization, MNEs innovation strategy is also expanding as never before. Generally, firms expand globally as a consequence of home based 'ownership advantages' to be exploited in foreign markets (Kuemmerle, 1999; Patel & Vega, 1999). MNEs usually restrict their R&D activity close to headquarter (Mansfield et al. 1979). However, in the early 1980's they started R&D in offshore locations to augment home base R&D capabilities. Major reason for dispersion of R&D activities was to secure new technological competencies distributed globally. Many R&D units are now working beyond the adaptation of products developed in home to local market. Many firms are acquiring new knowledge from the local environment for the parent unit at home (Zander, 1999; Pearce & Papanastassiou, 1999; Niosi, 1999; Zedtwitz & Gassmann, 2002). However, offshoring R&D by MNEs were restricted mainly in triad region (US, Western Europe, and Japan). In recent years new mode of organizing MNEs innovative activities are gradually emerging. MNEs around the globe are now eager to exploit developing countries' markets particularly the two emerging Asian major; China and India (Mrinalini & Wakdikar, 2008; Bruche, 2009; Krishna et al. 2012; Patra, 2014). Simultaneously, government of both these countries are creating conducive environment for MNEs with attractive policies like tax breaks, knowledge parks, and multiple knowledge hubs in major cities in the form of world class educational institutes. Policy and decision makers in these countries realized that communication among government, university and industry is the key to innovation and sustainable growth.

As seen from *Booz & company annual global innovation 1000 survey 2007*; the top 80 US MNEs spend about $ 80.1 billion out of US$ 146 total R&D fund. Out of their total $117 billion R&D budget top 50 European companies spend $51.4 billion in overseas. Top 43 Japanese firms spend 40.4 billion out of a total of 71.6 billion in overseas R&D (Jaruzelski & Dehoff, 2008). Although, global FDI flows have been severely affected worldwide recently by the economic and financial crisis, (FDI Inflows are likely to fall from $1.7 trillion in 2008 to below $1.2 trillion in 2010) it was recovered by 2010 with an outflow/inflow of up to $1.3–1.5 trillion in 2011 and reached up to $1.6–2 trillion by 2011 (UNCTAD, 2005; 2009). According *to World Investment Report 2005* (World Investment Report, 2005) MNEs spent about half of global R&D expenditures, and about two thirds of business R&D expenditures (World Investment Report 2005). These expenditures are significantly higher than many individual countries' Gross Domestic Product (GDP). The world's largest R&D spenders are concentrated in a few industries, notably IT hardware, the automobile, pharmaceuticals and biotechnology industry (World Investment Report 2005). MNEs play an important role in the innovative activities of their home countries and control or own a large part of the world's stock of advanced technologies (Narula & Zanfei, 2005). The figures of R&D spending and other literature from UNCTAD and various other studies show that the large MNEs are also key actors in the generation and diffusion of innovation. MNEs use different means through which innovation develops and diffuses across national borders. MNEs are also very responsive to the specific variations in needs and customs that are peculiar to any given country or local situation, i.e. local needs (Katz, et al., 1996).

Foreign Direct Investment (FDI) is one of the major instrument through which MNEs acquire existing assets abroad or set up new wholly owned activities (Greenfield investment) in foreign markets. Beside this there are other important procedures for example; trade, licensing, joint patents, and international technological and scientific collaborations. One of the major changes that have taken place in the post—2000 globalized era is that the corporate R&D at MNE headquarters is no more hierarchically integrated and concentrated in the home country or in the triad region (where MNEs are known to have conventionally operated). This has broken down and it is here argued that, the internationalization of R&D of 'one way relationship' of the 1980s has given way to 'two ways or multiple ways of relationships' towards globalization of R&D and globally distributed R&D for production and innovation.

This phenomenon of internationalization of R&D did not gain much attention of scholars till the early 1980's. Few early studies, for example Ronstadt (1977, 1978) Behrman & Fischer (1980) studied US based MNEs and observed that R&D activities of MNEs depend upon the various push and pull factors. A new trend emerged in late 1980's when there was rapid increase in foreign-funded and foreign-performed R&D in most industrialized countries. *OECD Science and Technology Indicators Report* and the *United States National Science Board Science and Engineering Indicators* reported in early 1990s, that there is acceleration in the internationalization of industrial R&D (Niosi, 1999). By the end of 1990s, however, it had become an important research area.

Scholarly literatures are available on the role of MNEs in the context industrially advanced countries of North America Western Europe and Japan. For example Mansfield et al. (1979); Behrman & Fischer (1980); Patel & Pavitt (1991) Zander (1999); Thursby & Thursby (2006) Niosi & Godin (1999); Gassmann & Zedtwit (1999); Belderbos (2003) have worked on various aspect of internationalization of R&D. However all the studies mentioned above are based on developed countries' firms doing R&D in other developed countries. The works on MNEs doing R&D outside developed countries are comparatively rare. So, strong theoretical framework is missing. The developing countries and their significance come into picture from the point of international technology transfer and trade and market prospects. However, studies on developing countries and emerging economies involving the role of MNEs are just emerging mainly from the perspective of these countries.

The discourse of globalization of R&D via MNEs and their R&D operations in the two emerging economics i.e. India and China has spanned the mass media, newspapers and commentaries in international relations. For example; *Intel India Design Centre* in Bangalore has about 1000 professionals; *Motorola*'s R&D centers in China has about 1300. *GE's John F Welch Technology Cen*tre in India houses more than 2000 engineers and technical staff. With over 100 patents and a strong mandate for research in new technology areas such as Windows Live, the *Microsoft India Development Centre* (MSIDC) based in Hyderabad continues to expand its operations (*Business Line*. March 12, 2007). Microsoft's latest search engine 'Bing' is developed from MSIDC Hyderabad and Bangalore centre.[1] IBM never used to operate outside Washington and Paris, but today it has two labs in India with over 500 scientists. These firms are developing significant number of their global products from their R&D centres in India. These developments in the recent years provided a good rationale and a potential ground for undertaking this paper.

The paper is organized as follows; section 2 broadly deals with the literature on linkages of firms including the literatures on firms' embeddness with the actors of local innovation system. Further, this section briefly reviews the literature of social network analysis as an analytical tool and the relevance of open innovation in the era of globalization of innovation. Following the literature review, section 3 and 4 discuss the objectives and methodology respectively. Section 5 deals with the results including the types and the depth of linkages of firms with different local entities. Network maps are drawn to identify the important actors in the innovation system. Finally section 6 comes up the concluding remarks and policy implications.

Linkages of MNE's R&D Units with Actors of Host Country's Innovation system

MNEs generate new knowledge by investing in R&D and circulate this knowledge through its dispersed network of subsidiaries. To remain competitive particularly in high technology industries, firms continuously access to new information, know-how, and ideas. Knowledge generation and assimilation is essential to success for a firm. Presently, the knowledge produces and generated around the world in in an unprecedented manner which world has never witnessed before. So, it is very difficult for a firm or any other single entity to keep track of all the development happens in various technology fields. There are new technologies emerging with the convergence of technologies. So, to remain competitive MNEs continuously observe and absorb knowledge from other organizations including domestic and international firms, government laboratories, and universities. In high technology sectors large firms are no longer the sole locus of innovative activity. The locus of innovation is dispersed like a "network" of inter-organizational relations. Moreover, the network-like structure of the organizations responsible for innovation is perhaps arising from the relative immaturity of the technological paradigm. Arora & Gambardella had pointed out that in today's globalized world innovation process requires an appropriate combination of new and different organizational establishments to combine specialized complementary assets, controlled by different types of actors (Arora & Gambardella, 1990). Firms can access external knowledge by engaging in inter organizational alliances. Empirical research has confirmed that strategic alliances are an important source of scientific and technological knowledge (Ahuja, 2000). Alliances can be defined as "formal, legal entities that take time to establish and, being costly in terms of managerial time and attention, must be limited in their number, and targeted to specific needs. In an environment where the nature, location, and type of potential knowledge sources are continuously changing, firms need to develop flexible mechanisms of knowledge acquisition" (Almeida et al. 2011).

In an Innovation System, the linkages among the various actors are very important for the best performance. Among the many other actors, universities, firms, government research institutes, venture capital firms, government policy, infrastructure etc. are important. It should be taken into account, that the efficient operation of a System of Innovation (SI) requires not only the activities of its component parts, but also the interaction among them. The innovative performance of a country depends to a large extent on how these actors relate and interact with to each other as elements of a broader system (Dahlman & Utz, 2005). Linkages of a firm can take in the form of joint research project, joint development of a product, personnel exchanges, joint patenting, technology licensing, equipment purchase, and also a variety of other channels. Better networking may lead enhanced resource flows to the companies. Therefore, the networks between the group of firms and extra-regional actors are of importance (Rickne, 2001).

MNEs are the main actors in knowledge transfer to the local firms in the developing world. Knowledge transfer occurs through the interactions with the local actors in the different stage of value chain (Reddy, 2011). From host country's perspective, MNEs technological knowledge is the major contributor to develop local technological capability. Various kinds of linkages among the foreign firms with local institutions in host country have major impact on the capability and resource development of these firms. Firm's capability building depends upon the scope, quantity and quality of linkages formed among the foreign firms and local institutions' interaction (Giroud & Scott-Kennel, 2009). MNEs linkages in a host country can be of various forms *backward, forward or horizontal.* The linkages where foreign affiliates acquire goods or services from domestic firm are called *backward linkages*. When foreign affiliates sell goods or services to domestic firms is called *forward linkages. Horizontal linkages* involve interactions with domestic firms engaged in competing activities (UNCTAD, 2001). However, not all value chain relationships are equally favorable for knowledge transfer. Several knowledge transfers occur unwillingly through the workers' mobility. Some knowledge transfer happens voluntarily. For example MNEs themselves want to increase the efficiency of their local suppliers for different steps in their value chain.

Firms embeddedness with the local innovation system

Firms very occasionally work in isolation to build their assets, but in interaction with other actors of the innovation system (Gulati, 1998, 1999). However, there are variations in the pattern of interaction of firms with the different actors in the innovation system. This variations is due to the of firm's embeddedness in their environment for creating knowledge to achieve competitive performance (Figueiredo, 2011). The embeddedness is important to accumulate capabilities for product, process or service innovation (Figueiredo, 2011; Andersson & Forsgrent 1996). The degree of subsidiary's embeddedness is a function of the adaptation between the subsidiary and the local actors of innovation system. Subsidiaries accumulate innovative capabilities over time. Improvements in innovative performance are depends on the embeddedness of subsidiaries in the local context. The frequency and the quality of the linkages depend on intra-corporate counterparts ('internal' linkages) and local organizations ('external' linkages) and are important to achieve innovation capability.

To study the external linkages this paper follows the typology (Table 1) developed by Ariffin (2000); Ariffin & Figueiredo (2006) and Figueiredo (2011). For this study these linkages are categorized into four types. The types of linkages are; *Joint research*, *Joint adaptation modification (JAM), Human resource recruitment- education & training (HET), Arm's length (AL)*. This typology makes difference between arm's length transaction and joint R&D. Increasing weights are given based on the degrees of quality of knowledge-intensive linkages. The linkages were ranked from 1 to 4 according to their intensiveness of the knowledge creation involved. Arm's length being the lower level of linkages is given the lowest score and the score increases according to the intensity of linkages. Joint R&D program is the highest level of linkages with deep involvement of different actors. This typology helps to map the degree of collaboration of subsidiaries with the local actors.

The increasing weights of the degree of collaborations was used to map the collaboration and linkages patterns of foreign firms and the actors of local innovation system using social networking analysis tools.

Network analysis

Social Network Analysis (SNA) is getting increasing importance in recent years. Based on mathematical Graph theory, it is a multidisciplinary approach widely applied in many fields of science and social sciences since the late 1970's (Scott, 1991). A social network is a set of individuals or entities which have some kind of relationships to some or all of the others in a group (Abbasi et al. 2012). In network analysis, the people or groups are called vertices, actors or nodes and the connections are edges, ties or links. An actor can be a single person, a group, or a firm. A tie could be a friendship between two people, cooperation, collaboration or common member in a group, or a business relationship between the firms (Newman, 2003; Hanneman & Riddle, 2005; Abbasi et al. 2012). As a useful tool to analyze the relationships between various actors, SNA is increasingly used in recent years in the innovation studies (Granovetter 1973; Wasserman & Faust 1994; Powell et al. 2005).

Table 1 Framework for explaining linkages of MNEs R&D units

Degree of Linkages	Rank	Type of external linkages with local organizations: universities, government research institutes, firms, suppliers and clients	
High	4	Joint research	Collaborative projects with local organizations on different types and degrees of research, development and design of new products, processes, joint problem-solving involving high degrees of trust
	3	Joint adaptation modification	Acquisition and sharing of knowledge with local organizations for basic or intermediate innovation activities
	2	Human resource recruitment, education & training	Recruitment of human resources and education and training programmes with local organizations
	1	Arm's length	Informal and /or one off type of interactions based on minimum exchange of information
Low/Lacking	0	No linkage	

(Source: Ariffin, 2000; Ariffin & Figueiredo, 2006 and Figueiredo, 2011)

In a social network relational ties connect between the different or same types of actors within a network. These ties can be informal or formal. If the line between two nodes is non-directional, then the network is called undirected; otherwise, the network is called directed. In this collaboration network, nodes are the foreign firms and the local entities or firms ties (links) are types of relations (arm's length relations, join development, joint R&D programs and so on) among them. The collaborations between firms, represented in a graph can be examined from a macro- (network-centered) or from a micro- (actor-centered) perspective. The macro-structure of a network is useful to measure the social structure that arises out of the physics of its connections (Li-chun et al. 2006). For example, in a networks where the actors connected within a short distances to all others are more likely to diffusion information quickly. The micro-structure of a network provides information about individual actors and their behavior in a network. For example, if an entity has more number of connections means it is more influential and have higher impact in the network (Degree Centrality). The micro-structure of a network analysis stressed on the measurement of Centrality. Centrality measures are the most important and widely used conceptual tools for analyzing social networks. The centrality measure (Faust 1997; Freeman, 1979) gives a fair idea which actor(s) are centrally located within the sample. All empirical studies try to identify the most important factors i.e., *degree, betweenness, closeness, and eigenvector centrality* within the network. The concept of centrality used in two-mode data, where data consist of a correspondence between two kinds of nodes, such as individuals and the events in which they participate (Borgatti et al. 2002, 2009; Newman, 2001; Scott, 1991, Wasserman & Faust, 1994). In this study uses the 2-mode concept for analysis of the actors and their positions in the networks. Here in this linkage analysis two different types of entities are involved i.e. the collaboration among foreign firms and local firms or educational institutes or government research institutes. This analysis also gives some indication of the potential flow of knowledge and communication between the different types of actors.

Open innovation

The closed innovation paradigms were popular concepts in 20th century. The innovation was considered as 'black box,' and industries were mainly characterized by mass production. Generally firms were strong, self-sufficient and corporate philosophy was to invest more in R&D to achieve radical innovation. In traditional or so called "closed model" firms use their own capability to generate and develop innovation to remain competitive in the market (Chesbrough, 2003; Chesbrough 2006; De Jong et al. 2008 page 11). Firms innovate using internal or external sources, then perfect the technology and make ready for commercialization. Like a funnel, the concepts narrowed down to the useful or beneficial concepts along with the companies' need. The failed projects or the concepts that did not match the corporate strategy, the ideas often remain unused (OECD 2008). The innovation process was dropped unyielding innovations, and firms were only interested with radical innovations to achieve monopolistic advantages. Firms were also cautious about the intellectual property (IP) and usually kept it among themselves from the potential rivals.

Collaboration in innovation process was not new concept. There are abundant literature available on inter or intra firm collaboration patterns. Various studies find that firms do not innovate in isolation rather co-operate with external partners in different steps of value chain. However, the openness in innovation process is becoming more prominent now-a-days as evidenced in popular as well as scholarly literature. The concept gained more popularity since 2003, with the term "Open innovation" coined by Henry Chesbrough. The concept, draws a great deal of attention among researcher and business communities worldwide (Chesbrough 2003; Chesbrough 2006). Business management professionals, scholars are emphasized the need of open innovation strategies as it is becoming an integral part of global corporate strategy (Backer et al. 2008). The uniqueness of the concept of "Open Innovation" is, it recognized the importance of both internal and external knowledge and a proper coordination of both will yield optimum benefit for a firm. The term "open" is generally related to many free software available in the market. However, the open innovation is firmly based on benefit shearing and on intellectual property protection (OECD 2008). However, the idea is still in germinating stage and primarily limited to the organizational level, but it is increasingly being discussed in the different level of innovation systems and related government policies (De Jong, et al. 2008).

In today's highly complex, competitive and globalized market, MNEs have to innovate and develop commercially viable products quickly. In this competitive global business environment, corporate R&D function has changed rapidly. To meet the pressing challenge to innovate more and quicker MNEs have changed their innovation strategies and adopted new approach. It is observed that important innovations are increasingly being done at small and medium size entrepreneurial companies. University and research laboratories are gradually interested in forming industry partnerships to commercialize their research. Even individuals are today eager to license and sell their intellectual property. Rapid developments of ICT particularly the recent development of the Internet and web technologies have opened new means to access worldwide talent quite easily. Even the major MNEs like International Business Machines (IBM), Eli Lilly Proctor and Gamble (P&G) are doing research with the new concept of open innovation, by using one another (even competitors') innovation assets (like products, intellectual property rights, and even R&D manpower) (Huston & Sakkab 2006). For example; P&G in 2000, realized that P&G couldn't meet its overall objectives by spending more on R&D for less return. The company reinvents the company's innovation business model by connecting ideas across internal businesses. By doing this, 50 % of P&G's innovation comes from outside the company. According to Huston, & Sakkab "*The strategy wasn't to replace the capabilities of our 7500 researchers and support staff, but to better leverage them. Half of our new products... would come* from *our own labs, and half would come* through *them*" (Huston & Sakkab, 2006).

As seen from the P&G's example, not even the largest R&D spenders are doing their entire R&D, rather increasingly tying up with other. Along with other activity like sales, manufacturing, MNEs have gradually shifted their R&D activities across borders along with their global value chain. Many MNEs are banking on outside innovation for new products and processes. As a result, world's innovation landscape had changed significantly. Now firms are gradually shifting their innovation model from a centralized approach to a globally dispersed integrated model (Bartlett & Ghoshal, 1989). New products and services are not only developed by one company but also in collaboration with partners such as suppliers, research institutes, competitors or even users (Hippel 2005). Thus the corporate are increasingly going towards open mode of innovation. The open innovation phenomenon is a complex issue and gaining increasing focus form different stream of academic discourse like *globalization of innovation, off sourcing of R&D, supplier integration, user innovation, external commercialization and application of technology* (Gassmann, 2006). Open innovation argues that innovation paradigm has shifted from a closed 'inbound open innovation' to an open 'outbound open innovation' model (Chesbrough & Crowther, 2006; Chesbrough, 2006). Presently, it has taken center stage with the recent debate on globalization of R&D and the potential for the R&D function outsourcing.

Objectives

Major objectives of this paper are as follows:

a) To analyze the nature and type of linkages these MNE's R&D centres are developing with local public and private R&D institutions and universities in the emerging economies
b) To examine the difference in type of linkage for example core domain (joint R&D) or peripheral domains (joint product development) in different industry group of ICT sector.
c) To understand the emergence of open innovation 'model' in the case of increasing foreign R&D activities in India.

Methods

In view of the objectives discussed above, this study is based on an in house developed database. The database has been developed with the collected information from various news sources. Many different newspapers are scanned form India, for example the *Hindu Business Line; Economic Times, Business Standard and* so on. Beside this the famous newspaper database, *Lexis-Nexis* was searched, using the keyword 'R&D centre and India' and all information about foreign R&D centres was downloaded. Moreover, information from firm's annual report and their press releases were collected and stored. The linkages of firms collected in this study are listed in Appendix.

The information collected from the above mentioned sources are stored in a database prepared using MS Access. It is a relational database, which contains separate data files. All individual record of firms stored with different fields like the name of the firms, address in India, year of entry into the Indian market, major products developed from Indian R&D units, investment in manpower, investment in R&D, linkages with different entities, joint venture linkages or other mode of alliances etc. The records from the databases were taken in MS Excel for further analysis. Networking software (for example Ucinet and Net draw) were used to draw the network maps of firms linkages.

The firms in the database are further classified using the Global Industry Classification Standard (GICS). This classification system has jointly developed by Morgan Stanley Capital International (MSCI), and Standard & Poor's (S&P). Only those inter-firms' agreements are being collected that contain some arrangements for joint research, technology transfer, joint development, human resource development or arm length relations. This method of information gathering, called "literature-based alliance counting" (Hagedoorn, 1995; Duysters & Hagedoorn, 1996; Hagedoorn, 2002). This method has its drawbacks and limitations. For example; only the information about the alliances or agreements which are publicly available in different news sources are collected. The information, which is not publicly declared, will be overlooked. Under reported, small and low profile firms are generally missed.

Despite these shortcomings, the method is widely accepted as seen from the MERIT-CATI database. This method is a fairly good source of empirical research and goes beyond the case studies (Hagedoorn, 1995; Duysters & Hagedoorn, 1996; Hagedoorn, 2002).

Results and discussion

MNEs create linkages when they are directly involved in relationships with other firms in the host economy (via transactions or alliance-based relationships within or across industries) and consequently influence the output, capability development and productivity of partner firms. Linkages, therefore, embody inter-firm transactions, interactions and on-going relationships. MNE's subsidiaries have the potential to embed themselves within different types of knowledge networks in the host country, to accumulate their capabilities for innovation in products services, thereby strengthening their competitive advantage (Figueiredo 2011). Subsidiaries accumulate innovative capabilities over time. Improvements in innovative performance are depends on the embeddedness of subsidiaries in the local context. The frequency and the quality of the linkages to the local organizations may be called as 'external linkages'. These kinds of relations are important for firms to achieve innovation capability. In order to accumulate their capabilities to innovate, most firms depend on a wide variety of knowledge-supplying partners. There are variations in the way firms create their capabilities. Additionally, firms very occasionally work in isolation to build their assets, but in interaction with other actors of the environment (Gulati, 1998). However, there are variations in the pattern of interaction of the firms with the different actors in the innovation system. This variations is due to the of firm's embeddedness with different actors in their environment to create knowledge to achieve competitive performance (Figueiredo, 2011).

To study the external linkages, the study follows the available typology described in Table 1 (Ariffin, 2000; Ariffin & Figueiredo, 2006; Figueiredo 2011). This typology makes a difference between arm's length transaction and joint R&D. Increasing weights are given based on the degrees and quality of knowledge-intensive linkages. For this study, the linkages were ranked from 1 to 4 according to their intensiveness of the knowledge creation involved. This typology helps to map the degree of collaboration of subsidiaries with the local actors.

Among all types of linkages, Arm's length linkages are considered the lower type of knowledge base interactions and given the score 1. In these kinds of interactions or relationships, the actors are not deeply attached with each other. So, the social closeness among the actors is lacking. These are generic and business-type of relationships involving exchanging of services and goods. However, through these types of linkages a firm may acquire different types of unique knowledge and skills.

If firms have some kind of human resources, education and training programs with local organizations, is considered higher level of linkages than Arm length transactions and given weightage of "2". The examples of these kinds of linkages may be as follows. *Intel* along with *NIIT* have jointly developed 'Multi-core' training curriculum in 2007.[2] *Texas Instruments* along with Jawaharlal Nehru Technological University signed agreement to impart training to faculty and students to educate them in digital signal processing, embedded systems and related areas.

In the next level beyond the education and training is the acquisition and sharing knowledge with local organizations for product development and research. These types of agreements are higher than the joint human resource development program and are given weightage of "3". For example *Intel India Development Centre* along with *Satyam* jointly implemented different strategic development projects.[3] *Freescale semiconductor, Intel, Texas Instruments, Honeywell, Mindtree* jointly developed *ZigBee* alliance protocol.

Collaborative efforts with local organizations on different types and degrees of R&D and design of new products, processes, and software and joint problem-solving involve the highest degrees of mutual trust. It is considered the highest level of linkages with the local actors and given maximum weightage of '4". The examples of these kinds of collaborative R&D projects are as follows. *STMicroelectronics* has set up joint R&D labs along with BTIS Pilani, IIT Delhi, IIT Kanpur, IISc in 2007.[4] *Infineon Technologies, IBM, Chartered Semiconductor, Samsung* have agreed for joint R&D for advanced 65 nm low-power and high-performance CMOS platform technology in 2006.[5] Indian Institute of Science, Bangalore (IISc) is the only institute outside the US, took part in Texas Instruments' premier research network of the top four leadership universities in the world.[6]

Types of linkages in India

Foreign MNEs in India conduct R&D in many different ways. According to Reddy (1997, 2011) the foreign firms in India may have wholly owned stand-alone R&D units. These kinds of R&D units are closely in contact with the MNCs' headquarters and report directly to the parent unit. It is discussed in the earlier section that MNEs linkages with different entities in India are in several different forms. It may be a joint venture R&D with Indian educational institutes, Indian companies or other foreign firms. The technology alliances can be with Indian companies, including outsourcing of R&D to Indian companies; and research collaboration with Indian universities and national research institutes (Reddy, 1997; 2011). It has also observed that in India there is recently many R&D service providers are emerging. Such service providers include both foreign and local companies. Indian R&D service providers have established their reputation globally as capable to deliver products and processes Also, India has a number of world class educational institutes to whom foreign firms prefers as collaborative partners. There are many examples of MNEs R&D units situated in Indian universities campuses (Krishna, 2012).

Among the total 698 linkages of foreign firms identified in this study in IT sector, the maximum numbers of linkages are observed as joint development programs. There are about 291 (41 %) joint development programs among foreign firms and other entities. There are 237 (about 34 %) joined R&D programs, 41 (6 %) joint human resources development programs and 129 (18 %) alliances can be considered as arm length linkages (Table 2). The

Table 2 Type of linkages among foreign firms and entities

Types	All ICT Sector	Technology Hardware & Equipment	Semiconductors & Semiconductor Equipment	Software & Services
Arm length	129	51	17	61
HRD	41	17	7	17
Joint Development	291	110	44	137
Joint R&D	237	91	42	104
Total	698	269	110	319

details analysis of linkages among different industry group shows that joint development programs are the most predominant form of linkages in ICT sector.

Linkages in India with different entities

Linkages of foreign firms are broadly categories into four categories as shown in Table 3. Foreign firms linkages with other foreign firms located in India are put in the first category. University linkages are put in second row, linkages with local firms and Indian government institutes are in 4th and 5th columns respectively. In Indian case, government research laboratories like Council of Scientific and Industrial Research (CSIR), Indian Council of Medical Research (ICMR) etc. are grouped under government research institutes. Beside the universities in the name, the premier Indian educational institutes like Indian Institute of Technology, Indian Institute of Science are categorized under universities.

In hardware industry group among the total 185 linkages 93 (about 50 %) are with the foreign firms followed by 56 (30 %) with the Indian firms and 27 (15 %) are with the Indian educational institutes.

In semiconductor industry group among 80 linkages identified, 50 (62 %) are with the foreign firms, 18 (23 %) are with the local firms, 11 (14 %) are with Indian universities or educational institutes and no linkages with Indian with government institutes.

Linkages of 106 firms are analyzed in software and services industry group. This group consists of three industries namely; *Internet software and services*, *IT services, Office Electronics*, and *Software*. The details of breakup of this group's firms are as follows: Internet software and services, 14 firms; IT services (28 firms) Office Electronics 1 firm Software 63 firms. The software industry firms constitute the major portion of the sample studies. Among the total 223 linkages identified in this group, 123 (55 %) are with the foreign firms followed by 58 (26 %) with the local firms. There are 31 (14 %) linkages with the universities and 4 (1.7 %) with the government or government funded research institutes.

It is evident from the Table 3 that, in total about 488 total entities 266 (about 55 %) are with the foreign firms and the rest are Indian institutions/firms. The firms mostly collaborate with other foreign firms. This is perhaps due to the firm's global alliance extended to the Indian subsidiaries. The linkages with the Indian firms are the second most prominent forms of linkages. There are many domestic firms which have formed alliances with the foreign firms R&D units. Indian universities and government research institutes are not

Table 3 Linkages of foreign firms with different actors of innovation system

	Total ICT sector	Technology Hardware & Equipment	Semiconductors & Semiconductor Equipment	Software & Services
Foreign firm	266	93	50	123
Indian educational institutes	69	27	11	31
Indian Firm	132	56	18	58
Indian government institutes	11	7	–	4
Others	10	2	1	7
Total	488	185	80	223

much prominent in the formation of linkages with the foreign firms. It shows that industry academia linkages are quite weak in India.

Collaboration networks

The linkage maps of the foreign firms in different industry groups of ICT sector are drawn using UCINET (Borgatti et al. 2002). From the databases of linkages of about 204 firms, the firms are further categories under three major industry groups. There are about 73 firms in Technology Hardware & Equipment Industry group; 26 firms in Semiconductor Industry groups and 106 firms in Software and Services Industry groups (see in Appendix). The collaboration network of firms is analyzed in two levels i.e. Macro level (whole network) and Micro (individual actor level). The following section will deal with the Macro (whole network) characteristics of the network.

The whole network structure of the different industry group is presented in the Table 4. In a network the measurement of average degree and the weighted average degree of the nodes show the closeness of the actors in a network. It is generally observed that in a network, the higher the average degree, the tighter the network is. Although in this study software & services industry groups has the maximum number of linkages with the local entities, the average degree of nodes in the networks of this study shows that the cooperation in this network members are not very dense.

The diameter is the length of the longest geodesic distance within components. Except the Software & Services, the diameter of the network is small means the network actors are not very far from one another. The density of a collaboration network is simply the proportion of all possible ties that are actually present. Among the all industry group semiconductor industry software industry the actors are closer than any other groups. However, there are less number of firms in this group. From the whole network level analysis it can be said that the collaboration network of firms are not very dense and a few members in the network has the controlling position in knowledge flows.

Micro level characteristics of collaboration network

In Micro level network measurements mainly deals with the centrality. Centrality measures identify the most prominent actors in a network. Centrality indicates one type of "importance" of actors in a network. It is a fundamental concept in network analysis to identify the "key" players (Freeman, 1979; Borgatti & Everett, 2006; Borgatti, 2005). The most important centrality measures are: degree centrality, closeness centrality and betweenness centrality. The following section will deal with the centrality measures in three industry groups.

Table 4 Structure of the whole network in different industry level

	Industry groups		
Characteristics	Hardware Industry	Software & Services	Semiconductors
Number of nodes	257	332	106
Number of edges	266	312	109
Average degree	1.440	1.378	1.350
Diameter	11	22	8
Average distance	4.882	5.096	3.862
Density	0.020	0.013	0.052

Technology hardware and equipment industry group

This industry group consist of three industries namely Communication Equipment, Computer peripheral and Electronic equipment and instruments. A few examples of industry wise collaborations are discussed in the following section.

Communication Equipment industry There are 43 firms in this industry of this sample of firms. In this industry group, among the university linkages *Cisco, Ericsson* and *Motorola* have joint R&D program with IIT and IISc. Cisco has the most number of linkages in India and majority of them are with the local firms.

Computer peripheral industry: Among the total 19 firms in this group, *Sun Microsystem* has the most number of linkages. However, *Hewlett-Packard* has the highest number of linkages with the universities. Among the many academic collaborations HP has research collaboration with Tata Institute of Fundamental Research on High Performance Computing (HPC) solutions at its Computational Mathematics Laboratory (CML) in Pune.[7] HP has also research collaborations with ISI - Kolkata, Indian Institute of Science, Bangalore, various Indian Institute of Technologies BITS Pilani and so on.[8] Beside research collaboration HP has also offered doctoral fellowship and sponsored students for various programs in International Institute of Information Technology (IIIT), Bangalore, IIIT Hyderabad and IIIT Allahabad, National Institute of Design (NID), Ahmedabad, Bangalore, IDC, IIT, Mumbai, Shristi School of Art Design and Technology, Bangalore and so on.

In this group of firms, other form of collaboration is also observed. For example; *Sun Microsystems* designed an *"eco consortium"* in India as part of its eco innovation initiative in 2007. The group formed by the members like *APC-MGE*, *Advanced Micro Devices, Hitachi Data Systems* and *Wipro Infotech.* The consortium worked together to address the issues like power consumption, space and limited infrastructure requirement. This consortium enabled customers to make their business eco-friendly and "green" and address technology infrastructure issues in the data center. The consortium partners shared various aspects of the technology according to their expertise. For example, Wipro Infotech provided system integration and scaling, APC-MGE dealt with the power and cooling systems. AMD provided energy-efficient computing technologies. Hitachi Data's green storage solutions enabled better use of storage and power consumptions. In this way the consortium aimed to achieve power efficiencies and better computational capabilities.[9]

Electrical equipment & instruments industry There are 11 firms in this group. *Agilent* has 7 various R&D partnerships with different universities or educational institute in India. Agilent accept or promote funding for doctoral research proposal from various IITs and IISc.[10] *LG* has collaborated with IIT Delhi in 2008 for the development of refrigerator compressor technology.[11] As discussed in the previous section Sun Microsystems has initiated *"eco consortium"* in India as part of its eco innovation initiative. Wipro Infotech, APC-MGE, Advanced Micro Devices and Hitachi Data Systems, are the members of the consortium.

Figure 1 present the collaboration network of firms in Technology hardware and Equipment Industry group firms based on the degree centrality measure. The network map was drawn from the different types of linkages of 73 firms with 185 different entities including

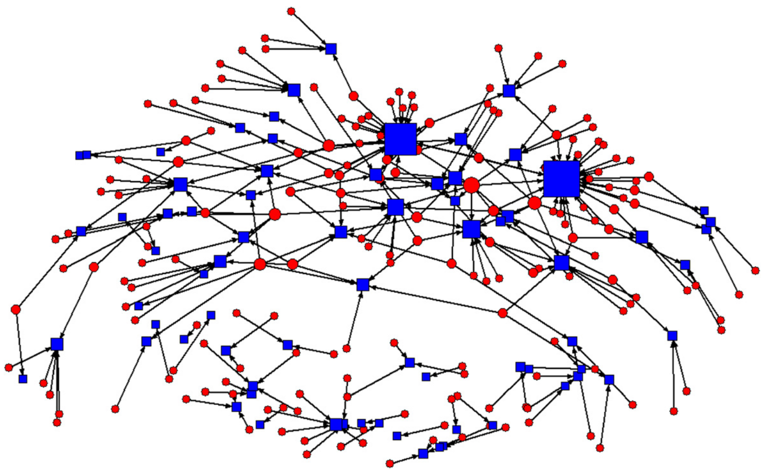

Fig. 1 Collaboration network in Technology hardware and Industry group firms

local firms, educational institutes, government research institutes and foreign firms with R&D units in India. It shows that Sun Microsystems (Sun was acquired by Oracle Corporation in 2010) had the maximum number of collaborations with different Indian entities, followed by Hewlett-Packard Co. and Cisco. Although there are other firms in this industry they are not occupying any knowledge controlling positions. The details centrality measures of top 10 actors are presented in Table 5.

Among the local actors Wipro Limited, Satyam Computer Services (Now Tech Mahindra), Reliance Communications, HCL Infosystems Ltd. are the promenent actors in terms of degree centrality. Again it is important here to note that Indian firms are more prominent in formation of linkages rather than Indian educational institutes or government research laboratories.

Semiconductor Industry group firms

The network map is drawn from the available linkages of 26 semiconductor firms (Fig. 2). Among the sample firms Intel Corporation is the most prominent actor followed by Texas Instruments Inc. and ARM Holdings plc. The major network cluster is being formed by the few top actors (Table 6). There are many firms which are not much prominent in terms of linkages.

Table 5 Centrality measure of firms in Technology hardware and Industry group firms

Name of the firm	Degree	Betweeness	Closeness	Eigenvector
Sun Microsystems	30	5691.85	21157	0.291
Hewlett-Packard Co.	25	6506.604	21109	0.158
Cisco Systems, Inc.	11	1619.832	21197	0.076
Toshiba Corporation	9	2138.17	21203	0.048
Fujitsu Ltd.	8	1002.171	21335	0.04
Mobi Apps	7	1909.533	21351	0.006
Telefonaktiebolaget LM Ericsson	7	1088.331	21215	0.044
Lenovo Group Ltd	6	1613.525	21279	0.013
Motorola, Inc.	6	992.875	21299	0.013
Airwide Solutions	6	870	21681	0

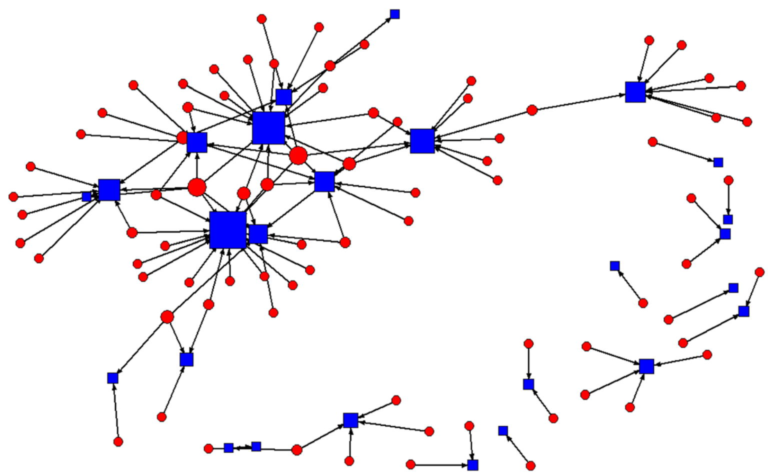

Fig. 2 Collaboration network in Semiconductor Industry group firms

Intel has maximum linkages followed by *Texas Instruments* and *Freescale semiconductor. STMicroelectronics* has also set up joint research and innovation lab with different IITs, IISc and BTIS Pilani.[12] *Texas Instruments* has collaboration with IIT Kharagpur and IISc. *Texas Instruments* recognize IISc as premier research network of the top four leadership universities. With IIT Kharagpur, *Texas Instrument* develops semiconductor technologies that are aimed at improving the quality of healthcare diagnostics and reducing its costs.[13]

Among the semiconductor firms, *Intel, Freescale, TI, Honeywell* and *MindTree* formed *ZigBee alliance*. ZigBee is a new protocol, based on the IEEE 802.15.4 standard. The alliance was formed in December 2004 to promote and build upon this standard. The ZigBee Alliance is an association of firms working together. The main advantages of ZigBee are that it consumes less power and it is open standard. It aims to develop reliable and low cost products which consume less power, wirelessly networked, and based on an open global standard.[14]

In this industry group, among the collaborating local actors, einfochips, Wipro Limited, Indian Institute of Science Bangalore (IISc) Indian Institute of Technology (IIT) Bombay, Satyam Computer Services (Now Tech Mahindra) are the prominent

Table 6 Centrality measure of firms in Semiconductor Industry group firms

ID	Degree	Betweenness	Closeness	Eigenvector
Intel Corporation	16	837.963	4002	0.266
Texas Instruments Inc.	14	704.687	4008	0.242
ARM Holdings plc.	9	810.091	4020	0.092
Advanced Micro Devices, Inc.	8	365.31	4050	0.074
ATI Airtest Technologies Inc.	7	399	4132	0.006
Free scale Semiconductor, Inc.	7	280.871	4026	0.09
Nvidia Corporation	7	266.144	4024	0.118
Applied Materials Inc.	6	345.387	4026	0.096
Xilinx, Inc.	5	229.203	4040	0.052
Broadcom Corporation	4	9	10712	0
Portal Player	4	6	10816	0

actors. It is also important to note here that educationational institutes like IISc and IITs are important collaborating entities with the semiconductor firms. This shows the strength of Indian university or educational research institutes in this areas of research.

Software and services industry group

Linkages of 106 firms are analyzed in this group (Fig. 3). The details of breakup of this group's firms are as follows: Internet software and services, 14 firms; IT services (28 firms) Office Electronics 1 firm Software 63 firms. *Microsoft* and *IBM* are the most prominent actors in this group. IBM has a number of collaborative projects. For example; there are alliance among *IBM, Chartered, Infineon*, and *Samsung* (ICIS). The alliance develops sample chips in advanced 65 nm low-power and high-performance CMOS platform technology. Beside this, *IBM* is also the part of *'Cloud Computing Consortium'* involving many firms. *IBM* has tied up with *Google* for cloud computing,[15] *Yahoo* tied with IIT Hyderabad, Tata Computational Research laboratories for Cloud Computing research.[16]

Satyam, Microsoft and *Dell*, formed a consortium for building its next-generation research analyst workbench on Microsoft's technology platform.[17] Also Microsoft has various types of collaborative development program with different IITs in open source platforms.[18]

The top 10 actors in this industry group with their centrality measures are given in Table 7. Wipro Limited, Tata Consultancy Services (TCS), HCL Infosystems Ltd, Infosys, Satyam, International Institute of Information Technology-Hyderabad are the major collaborating entities among the local firms.

Open innovation

As discussed in the literature review section, open innovation is the latest corporate philosophy firms implement to combine in-house research, expertise, and capabilities with external knowledge, expertise to accelerate innovation in product and technology development of the firm. More and more firms are shifting their innovation policy towards 'open innovation model' in India irrespective of the sector

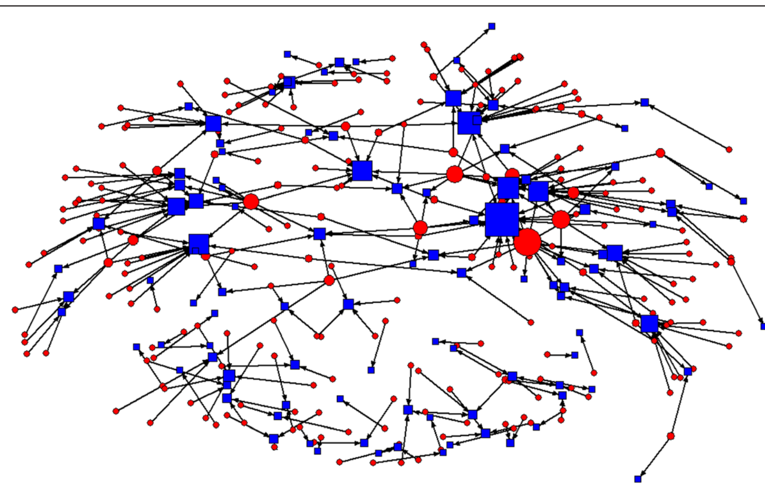

Fig. 3 Collaboration network in Software and Services Industry group firms

Table 7 Centrality measure of firms in Software and Services Industry group firms

Name	Degree	Betweenness	Closeness	Eigenvector
Microsoft Corporation	19	4917.794	50421	0.378
International Business Machines Corporation	12	2452.467	50555	0.078
BEA Systems, Inc.	11	2719.94	50441	0.25
BMC Software, Inc.	10	1598.619	50499	0.167
Red Hat, Inc.	10	1835.892	50593	0.01
VMware, Inc.	10	3962.104	50433	0.06
ASG Software Solutions	8	1709.487	50635	0.008
Cognizant Technology Solutions	8	1246	50753	0.017
Adobe Systems Incorporated	7	1440.637	50581	0.126
Computer Sciences Corporation	7	1176.697	50669	0.006

and industry. With this latest trend open innovation forms a unique foundation for India academia and industry to intensify their ties with western scientific and industrial R&D institutions. Firms realized that industrial value chain can possibly be achieved with mutual knowledge shearing with academic and also with industrial partners. The following section is dealing with the few cases of innovation models by the foreign firms in India. Some of the prominent examples of open innovation modes are as follows:

Xerox Corp established its offshore R&D center in Chennai in 2012 which is the sixth such center around the world. The primary focus of this motivation was to capture the Indian emerging market, collaborate with the Indian academics, researchers and even customers. Xerox's global CTO Sophie Vandebroek told in a press statement that Chennai R&D unit will be *'based on a new model of collaborative research and open innovation'* (Xerox India hub to follow open innovation model', March 22nd 2010). Dr. Meera Sampath, director of the Xerox India Innovation Hub further asserted that "*Open Innovation is at the core of how we conduct research not only at the Xerox India Innovation Hub, but also at Xerox research centers around the world.…Linking the talent in India with Xerox's 500 scientists at our centers in the U.S., Canada and France will allow us to leverage the power of truly global innovation networks and engage in cutting-edge research to create unique value for our customers around the world."* (Xerox Launches Innovation Hub in India, March 17th 2010).

Software giant ***Microsoft*** also promotes as well as encourage open innovation program in India. In 2013, Microsoft along with Coimbatore based KGISL Group of Institutions started an innovation centre. The program aimed to increase the employability of students by giving a platform for corporates to hire Microsoft technology certified students of high caliber for internship and placements. According to the Microsoft India official "*..the programme would help students to improve their employability"*. The programme will offer 250 internship opportunities and 100 employment opportunities for students (Microsoft to open innovation centre at KGISL, May 9th 2013).

Indian Institute of Technology (IIT) Indore and ***Computer Science Corporation (CSC)*** in India signed a memorandum of understanding (MoU), for IIT Indore to join the Collaborative Open Innovation Network (COIN). This initiative was started by CSC to promote and nurture upcoming talent. According to Ganesh Swaminathan, CSC director and head of Open Innovation program, *"…we are extremely proud to be associated with a premium institute like IIT Indore. With the COIN program we aim to bridge the gap between the industry and academia, which has been a longstanding issue for India. We believe that a student on the threshold of joining tomorrow's workforce should be given adequate exposure to real-world trends and industry expectations to help them learn and get hands-on experience with proven global work processes and practices"* (CSC in India and Indian Institute of Technology Indore to Collaborate on Promoting Talent, News Release—October 4th, 2012).

Dell Inc. India R&D centre has adopted an open innovation model wherein it collaborates and co-innovates with customers, start-ups, universities, partners and its internal R&D teams. "*..we have signed an MoU with IIT Chennai where a small team of three-four engineers from Dell will work on the next version of our High Velocity Cloud project, along with a professor and three students from IIT Chennai. We are working on a similar MoU in Bengaluru, where we are considering partnering with Indian Institute of Science and NIT Suratkal with a small team of seven-eight people in server systems software, systems management and software defined data centres,"* (Dell makes India its second research hub outside the US, December 4th 2014).

Conclusions

This paper explored the structure of linkages of foreign R&D centers with institutions in India. Much of the focus has been to explore the way these linkages manifest with the local universities and public research institutions, local and foreign private business enterprises and their R&D centres. The main purpose of this exploration, beyond linkages between foreign and Indian entities, was to understand how open innovation concept is unfolding in the Indian context. Analytical framework was useful to explore globalization of R&D and the nature and character of linkages through some indicators and measures.

Among the total of 698 linkages of foreign firms, we have considered ICT and allied sectors for this study. In India, linkages were mostly on joint product development program (291 links) followed by joint R&D (237 links). However, firms were almost equally involved in these two types of activities. Also, there were a number of human resource development programs conducted by foreign firms. This might be because of Indian firms were active in peripheral part of the MNEs value chain. In ICT sector foreign MNEs in India developed linkages more towards low and high-end service mode rather than joint R&D.[19]

Among emerging Asian economies, particularly India is not only seen as one of the biggest markets but is preferred due to emerging S&T and R&D ecosystems and knowledge hubs in the ICT sector. The main advantage is that the Indian innovation eco-system is endowed with huge reservoir of talented and highly skilled human resources together with market potential in ICT knowledge hubs in Bangalore, Chennai, Delhi National Capital Region, Pune and Hyderabad. Foreign firms were increasingly shifting their R&D and Global Development Centers in these regions. Now many foreign firms were moving to capture these markets and also to exploit the huge talent and knowledge pool. As a result, the collaboration between global

MNEs and local Indian firms were increasing. However large firms and their R&D units are operating in India from a long time with considerable links with local entities. For example GE*, Microsoft, Texas Instruments etc.* had established units in India since long and their linkages in India were more with different actors of innovation system compared to other MNEs in India.

Reddy (1997) observed that foreign R&D units in India were closely linked with corporate R&D headquarters in the parent countries. His study on Global Technology Units (GTUs) indicated that they are predominantly dependent on parent company for core R&D and innovation needs for operating at global level. They were reluctant to move beyond the triad (USA, Western Europe and Japan). However, the situation has changed in the last decade.

Our study reveals that foreign firms and MNEs preferred Indian firms and R&D institutions as their alliance partners for R&D and innovation. For example in the ICT sector, out of 488 linkages there were about 266 (about 55 %) linkages were with the foreign firms; 132 (27 %) with the local firms; and 69 (about 15 %) the Indian educational and R&D institutes. Similar trends were observed in disaggregated exploration of three industry groups in the ICT sector. University and government research institute were less preferable linkage partners compared to the foreign and Indian firms in India. Even though 15 % of linkages with higher educational and R&D institutions indicate lower statistical figure, this linkage is rather very crucial and generally cannot be quantified. Such links feed into long term R&D and global innovation strategies of MNEs. For instance, IBM laboratories in Delhi collaborate with IIT Delhi on long-term R&D problems for global innovation. Adobe India Ltd in Noida and Bangalore, which employ over 1000 software personnel, developed most of their products in India such Acrobat Reader, Photoshop among several others for global markets. Indian software firm Infosys that placed nearly 13,000 professionals in their worldwide units is part of Automotive Open Systems Architecture—Autosar. It networked with global auto manufacturers involved in R&D and standardization of software for auto electronics innovation. Similarly, Tata Consultancy Services with 89 000 employees operating in 47 countries develops software solutions in collaboration with American Express, Microsoft and GM among others.[20] There is some evidence that software high end services are getting more and more integrated with what we conventionally understand by R&D. Software high end and innovation end of the R&D spectrum are closely tied and integrated. This however needs to be further explored.

A number of firms also formed alliance for example with consortium of Green computing, Cloud computing etc., along with the other foreign and Indian firms. Firms are also moving towards more open and globally dispersed innovation model. Our empirical exploration of ICT sector reveals that Indian based local and foreign firms and their R&D and innovation centers are emerging as important sources of Indian knowledge hubs for global innovation networks and chains. Ernst (2005:61) in a revealing way indicated that MNEs are 'increasing their overseas investment in R&D, while seeking to integrate geographically dispersed innovation clusters into global networks of production, engineering, development and research'. There is a strong empirical evidence of this in this study in the case of India. In a revealing way Chesbrough's open innovation is in full alignment with the emerging trend of global networks of production and globally dispersed innovation in the case of global MNEs. In this sense there are many examples of open innovation models adopted by foreign firms in India. R&D and innovation centers of large global firms in India reflect Chesbrough's open innovation 'model'. Not only ideas but critical R&D inputs and R&D down stream innovation activities such as designing, branding marketing strategies flow from India (to large corporations) to home based firms (to inside the firms) and vice versa. The nature and character of R&D and innovation, which was earlier in the 1990s confined to mainly adaptive technology, has now moved into the realm of creative and open innovation mode. However, a more robust open innovation model or process is emerging, the Apple's I-Phone being a case in point. There is a trend of adopting globally dispersed and open innovation modes in the operations of USA and Western Europe MNEs and their global R&D centres. In the last decade they have moved rapidly into Chinese and Indian based locations. However, hypothetically this does not seems to be the case with East Asian based MNEs in Japan and South Korea. We need further empirical research to test this hypothesis.

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[9]Sun Micro forms green alliances Business Line 30th October 2007

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[14]Built 'Smart with ZigBee Business Line March 6th 2006

[15]IBM, Google forge software alliance EE Times 6th May 2008

[16]Tata Sons arm, Yahoo! tie up for cloud computing research Business Line March 26th 2008

[17]Satyam to work with MS Dell Business Line December 5th , 2003

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[19]It may be noted that in the last decade, much of the high end software services from Indian firms is closely integrated with R&D in power, auto, smart grids, finance, insurance and several other sectors. Software professionals work in close collaboration with R&D personnel which was not the case in India in 1980s and 1990s.

[20]See also (Krishna et al. (2012))

Appendix

Table 8 Linkages of following firms are used in this study

Technology Hardware & Equipment Industry group firms (73 firms)	3Com Corporation, Acer, Adaptec, ADC Telecommunications, Agilent, Airwide, Alcatel-Lucent, American Megatrends India Pvt. Ltd., ArchPro Design Automation, Aruba Networks, ASUSTeK Computer Inc/ASUS Technology Pvt. Ltd., Aztek Networks, Barco NV, Brocade, China Wireless Technologies Ltd./Coolpad, Ciena Corporation, Cisco Systems Inc., C-Mac Industries Inc., Comverse Technology Inc., Coolpad Software Tech (Shenzhen) Co. Ltd., Dell Inc., Diebold Incorporated, D-Link, ECI Telecom Ltd., Electronics For Imaging Inc., EMC Corporation, Emulex, Extreme Networks Inc, Flextronics, Fujitsu, Genband, Hewlett-Packard, Hitachi, Ltd., Huawei-3Com, Infinera, IronPort systems, Ixia, Juniper Networks, Kyocera Wireless Corp., Lenovo, LG Electronics, Life Size Communications Inc., Lucent Technologies, Metro Optix Inc, Mobi Apps, Motorola, Inc. National Instruments, NCR Corporation, NEC Electronics Corp., NeoAccel, Nokia Corporation, Nortel, Patton Electronics Company, Polycom Inc., Powerwave Technologies Inc., ProCurve Networking Inc., Qalcomm, Quantum, SanDisk, SCM Microsystems, Silicon Graphics Inc., Sony Ericsson (Sony Ericsson Mobile Communications A.B.), Sun Microsystems, Tandberg, Tekelec, Tektronix Inc, Telefonaktiebolaget LM Ericsson, Teradata Corporation, Topspin Communications, Toshiba Corp., Tyco International Ltd (Tyco Electronics), UTStarcom, Wyse Technology Inc.
Semiconductor Industry (26 firms)	Alliance Semiconductor, AMD, Analog Devices, Applied Materials Inc., ARM Holdings plc, ATI Airtest Technologies Inc., Broadcom, Conexant Systems Inc, Cypress Semiconductor, DiBcom, Freescale Semiconductor Inc., Globespan Virata, Infineon Technologies, Intel Corporation, Nvidia Corporation, NXP Semiconductors, Portal Player, Qualcore Logic Inc, Renesas, Samsung, Skyworks, ST Microelectronics, Texas Instruments Inc, Tundra Semiconductor Corp., VIA Technologies Inc., Xilinx Inc.
Software and Services Industry (106 firms)	Accenture, Adobe, ADP Wilco Limited, Airbee Wireless Inc., Amdocs Ltd. Ariba, Inc., ASG Software Solutions/ Allen Systems Group, Inc., Atrenta Inc., Autodesk, Inc., Automatic Data Processing, Aventail Corporation (Merged with sonic wall), AXIOM Design Automation, BEA Systems, BMC Software, Borland, Bubble Motion, Business Objects S.A., CA Inc., Cadence, Canon Inc., Capco Group, Capgemini , Citrix Systems, Cognizant Technology, Computer Sciences Corporation, Connectiva Systems, Convergys Corporation, Cordys, CoWare, eBay Inc., EMAGIA Corporation, Emptoris Inc. Ensim Corporation, FCG Software Services Inc., Fortinet Inc., Global Automation Inc., GlobalLogic Inc., Google, i2 Technologies, Iflex (owned by Oracle), International Business Machines Corporation, iGATE Corp., IKOS Systems, InfoPro Corporation, Infor Global Solutions (Formally BAAN Software), Informatica Corporation, InfoSpace, Inc., Intec Ltd., Intellisys, Interwoven Inc., Intoto Inc. (Acquired by Freescale Semiconductor), Kanbay International, Inc., Keane International India Private Limited, Kronos Incorporated, Latens Systems Limited, Logica PLC MACH S.à.r.l. Magma Design, McAfee Inc., Mentor Graphics, Microsoft, NDS Group, Nokia Siemens Networks, Novell Inc., Oracle Corporation, Parametric Technology, Pegasystems, Pervasive Soft, Rainbow Technologies Inc, Red Hat, Sanovi Technologies Corporation, SAP, Savvion, Selectica, Sequence Design Inc., SolidWorks Corporation, Solix Technologies, SonicWall Sonim Technologies, Staccato Communications Inc., SumTotal Systems Inc., SunGard , Symantec, Symphony Service Corp., Synopsys Inc., Synplicity Inc., Tekla Corporation, Telcordia Technologies Inc, Telenity, Tensilica Inc., Tibco Software Inc., Torry Harris Business Solutions Inc., Traian, Trend Micro Inc, Ubics Inc., UGS Corp., Unisys Corporation, USinternetworking Inc., Vanu Inc., VeriSign Inc., Veritas Software, Virtusa Corp., VMware Inc. Wind River Systems Inc., Witness Systems Inc., Yahoo! Inc., Zoho Corporation (formally AdventNet, Inc.)

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
SKP has collected data and compile the database. Both the authors have equal contribution in preparing the manuscript. VVK has presented the earlier version of the paper in SOItmC and KCWS 2015 conference 14-18 June 2015, Daegu, South Korea. All Authors read and approved the final manuscript.

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