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Communities, knowledge, and innovation: Indian immigrants in the US semiconductor industry

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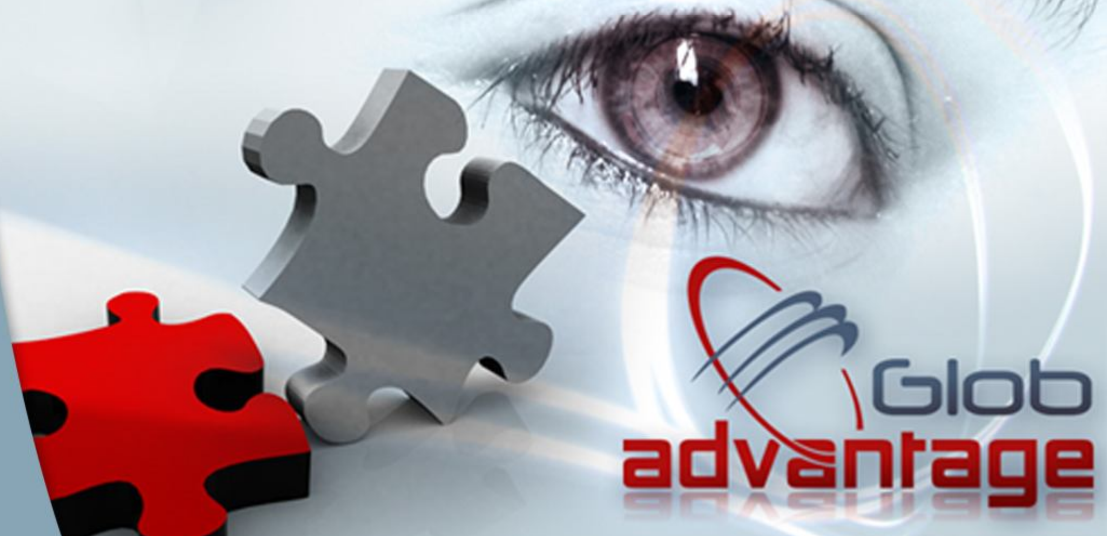

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Indian Immigrants in the US Semiconductor Industry

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ABSTRACT

This paper investigates the influence of technological, geographic, and ethnic communities on the innovativeness of Indian inventors. We study Indian inventors in the semiconductor industry in the US and examine their patenting profiles between 1975 and 1999 to identify the influences on the quantity and quality of their innovations. We find that inventors who rely on knowledge from technological and geographic communities enhance their innovativeness. Knowledge from the ethnic Indian community is related to inventor innovativeness in the form of an inverted U. The negative effect of knowledge gained from the ethnic community on innovativeness is pronounced for experienced inventors.

Immigrants play an important role in the technology intensive sectors of the US economy. They make up nearly 25% of the US scientific and engineering workforce, compared to only 10% of the total workforce and almost 50% of all scientists with doctorates in the US (Kerr, 2008). Immigrants of Indian origin are of particular importance in high technology areas of the US economy. A survey by Saxenian (1999) suggests that about a quarter of firms in Silicon Valley are led by immigrants of Indian or Chinese origin. A look at patents filed in the US suggests that an important role is played by inventors of Indian origin in the fields of electronics, biotechnology, and chemical engineering.

Research on ethnic groups suggests that membership in an ethnic community can enhance business success. Redding (1995), looking at Chinese family businesses, shows that informal relationships and practices within the community enhance performance. Kerr (2008) finds that knowledge diffuses within ethnic communities even across borders and enhances manufacturing outputs in the country of the immigrants' origin especially in East Asia. In the international trade arena, ethnic communities are seen to increase trade across countries (Rauch and Trindade, 2002). While ethnic communities appear to enhance entrepreneurship and economic activity of their members, we know less about their influences on knowledge sharing and innovation. Our paper investigates the role played by the ethnic community in influencing the innovativeness of Indian inventors in the US semiconductor industry. As professionals, these inventors can be seen to simultaneously belong to several social communities [1] (including technological and geographic communities). These communities are not mutually exclusive and influence knowledge flows, economic activity, and innovative ability. Given that ethnic Indian inventors often have access to technological and geographic communities, does the ethnic community provide new and unique knowledge and therefore have a positive influence on the quantity and quality of their innovations? Or do the ties to the ethnic community lead to over-embeddedness and therefore

[1] In this paper, we use the terms social communities and networks interchangeably to represent 'sets of recurrent associations between groups of people linked by occupational, familial, cultural, or affective ties' (Portes, 1998, page 8).

constrain innovativeness? Finally, does the usefulness of membership in the ethnic community change over the inventors' careers?

We answer these questions by using US patent data to identify Indian inventors in the semiconductor industry in the US. We look at their patenting profiles between 1975 and 1999 and identify the influences on the quantity and quality of their innovations. By examining the citation patterns of the patented innovations of these inventors, we are able to identify the extent to which they rely on knowledge from ethnic, technological and geographic networks. We then assess the impact of the knowledge drawn from these social communities on their innovativeness. As expected, we find that for Indian immigrants, a greater reliance on knowledge from technological and geographic networks enhances their innovativeness. However, we find that, as hypothesized, an emphasis on knowledge from the ethnic Indian community is related to inventor innovativeness in the form of an inverted U. The negative effect of ethnic communities on innovativeness is pronounced for experienced inventors. Hence, we find that, in some instances, Indian immigrant inventors absorb and use knowledge from others of their ethnicity even when this is detrimental to their innovativeness. Finally, we observe that the mobility of inventors either across organizations or geographic regions enhances their innovativeness.

The paper proceeds in the following sections. First, we develop our theory and hypotheses regarding the relationship between innovativeness and use of knowledge from various social communities. Next, we explain how we identify Indian immigrant inventors, use of patent and other data, and describe our methodology. Finally we present our findings and discuss the results, limitations, and extensions of this study.

SOCIAL CAPITAL, KNOWLEDGE AND INNOVATION

Since the 1970s, there has been an influx of immigrant (often graduate) students, predominantly from India and China, in to the United States. Many of these students reside and work in the U.S. after completing their education and, by many accounts, have largely been successful economic actors in terms of their involvement in R&D and entrepreneurship (Florida, 2004). Indian immigrants, with a strong technology bent, often work in industries like chemicals, biotechnology, information technology and semiconductors and play a prominent role in Silicon Valley, and other high technology regions like the North East corridor and the North Carolina research triangle. They have formed powerful immigrant associations (such as the Indus Entrepreneur) to foster business and engineering knowledge exchange among members (Saxenian, 2002). The social and economic activities of Indian immigrants appear to be intricately entwined.

The view that economic action is colored by social interaction is well accepted by economists. Sociologists, not surprisingly, take a stronger view suggesting that exchange decisions are embedded in ongoing social relationships and that economic action is shaped by social context (Granovetter, 1985). Regardless of where one stands along this spectrum, it is well accepted that individuals make decisions and take actions within a social context and the results of these decisions (and the associated actions) may, or may not, be oriented toward, or aligned with, economic efficiency.

Immigrants often belong to a social community that gives them access to resources based on the durable relationships embodied in the community. This is referred to as social capital (Coleman, 1988; Bourdieu, 1986). The motivation for membership and for engaging in exchange of resources within a community may be instrumental (or based on calculative and rational expectations). These instrumental exchanges within a social community are based on norms of reciprocity where there is an expectation of returns for the resources shared (even if the precise nature or the timing of these returns is not specified). The expectation is based on enforceable trust through social sanctions by the community (Portes, 1998). Exchange of resources based on social capital could also have a non-rational motivation. It could be motivated by altruism and common values and norms, where the participants feel a need to share or transfer resources within a group guided by a sense of shared identity. This motivation does not necessarily include an expectation of return or reward for one's actions (Nahapiet and Ghoshal, 1998). We argue, later, that for membership in geographic and technological communities, instrumental motivations appear to dominate, while for ethnic communities, altruistic motivations appear to be strong.

Regardless of the motivation for membership, social communities can have important implications for firm level outcomes such as enhanced access to equity (Batjargal and Liu, 2004), better protection of property rights (Peng, 2004), increasing survival rates (Lee, Lee and Pennings, 2001), greater entrepreneurship (Walker, Kogut and Song, 1997) and absorption of knowledge spillovers (Owen-Smith and Powell, 2004). Social communities also have individual level outcomes with positive effects on employee career advancement (Podolny and Baron, 1997), compensation (Burt, 1992) and managerial innovation (Rodan and Galunic, 2004).

One of the acknowledged benefits of social capital, highlighted by Adler and Kwon (2002), is access to knowledge and the enhanced ability to understand, interpret, and apply this knowledge. Dyer and Nobeoka (2000) suggest that social communities permit the identification of appropriate referrals to locate new knowledge. Relationships embedded in social communities then serve as pipes that enable the flow of information and resources between individuals within the social structure (Owen-Smith and Powell, 2004). These relationships facilitate the flow of high quality information since they permit rich exchanges between members (Larson, 1992). One of the advantages for communities is that they not only permit the sharing of knowledge but also enable the creation of trust and reciprocity that are critical for attributing saliency and absorbing knowledge (Granovetter, 1992; Coleman, 1988). Uzzi (1999) points to the role of social communities in permitting the flow of tacit and complex information and facilitating joint problem solving. Social communities not only facilitate the sharing of knowledge but also the creation of new knowledge by fostering collaboration that leads to the generation of alternative perspectives on research problems and application of solutions in new situations (Powell and Smith-Doerr, 1996), Thus, social capital is particularly important in high technology areas where inventors need to keep up with emerging ideas and knowledge from disparate sources.

Inventors in high technology regions use social interaction to regularly share information across organizational boundaries (von Hippel, 1988).

Social capital has advantages but may also have some downsides. The very features of social communities that facilitate exchange have costs associated with them. Portes (1998) provides interesting examples of social communities in Indonesia and Ecuador where membership in the community implies the need to share resources even when it leads to negative outcomes for the individuals involved. Solidarity between members of the community, often looked upon as one of the positive aspects of social capital, suggests a commitment to established norms, practices, people and ways of doing things. This solidarity may also be constraining to members and may limit the investigation of new knowledge and approaches. Norms of solidarity reduce exposure to, and relevance of, knowledge available beyond the boundaries of the group (Kern, 1998). Powell and Smith-Doer (1994) put it succinctly when they say that “the ties that bind may also turn into the ties that blind”. Since group knowledge, though useful, may be limited to narrow niches, this may be harmful to a member of the group and result in over-embeddedness. Uzzi (1996), in the study of firms in the New York fashion industry, finds that over-embedded firms are sealed off from knowledge that exists beyond the boundaries of the community. Therefore, over-reliance on a social community may have negative implications particularly for those seeking to innovate or explore new technological territory (Gargiulo and Bernassi, 1999). Finally, Portes (1998) suggests social capital can also create lock-in. The expectations of members for reciprocity and enforceable trust make it difficult for an individual, once a part of a community, to strike out in new directions. This can serve to lock-in players to the existing paths and approaches of doing things across time, thereby restricting their personal initiative and ability to innovate.

The nature of social communities may dictate the balance between the potential benefits and costs of membership as they relate to knowledge transfer and innovation. First, while social communities facilitate resource (including knowledge) sharing between their members, these resources are not always useful to the recipient of the knowledge. If most individuals in a social community are motivated to engage in exchange for instrumental or rational objectives associated with increasing their economic outcomes, they are likely to only source resources that are economically useful for them. However, if their membership in a community is based on altruistic motivations, and their actions are governed by expectations of solidarity, they may access and use resources that are not best aligned with positive economic outcomes such as innovation. Second, social communities may vary in the extent to which they are parochial (Bowles and Gintis, 2004) and permit members to participate or move beyond the boundaries. To the extent that members can choose communities and move between them, actors can source knowledge in a strategically useful way, in order to maximize their innovation. If actors are constrained from moving across the boundaries of the community this could limit their innovativeness. This is even more important in a dynamic and changing environment, where the sources of relevant knowledge are likely to change over time. Communities whose membership is dynamic are likely to provide greater access to useful knowledge and this could result in higher levels of innovativeness for their membership. Thus not all social communities may be equally beneficial for individuals seeking knowledge for innovation.

Innovative individuals within the Indian immigrant community simultaneously belong to, or potentially have access to, several social communities. In addition to the ethnic Indian community to which they belong by virtue of the common heritage, culture, and experiences, they have access to geographic and technological communities as well. This places an important question on the table. Given the availability of alternative social communities to source knowledge, how useful is knowledge drawn from ethnic communities to the innovativeness of the individual inventors? We develop hypotheses exploring the relationship between the use of ethnic and other social communities to the innovativeness of Indian inventors in the US.

Geographic Communities, Technological Communities, and Innovation

More than a century ago, the father of neoclassical economics, Alfred Marshall (1920), noted that economic activity tends to cluster in geographic regions that are rich in the 'atmosphere' of knowledge. The importance of geographic regions to economic development has been a persistent theme in economic sociology. Jane Jacobs (1969) argued that the social and economic linkages among diverse players generate and sustain growth of cities. The presence of spatially concentrated social communities has been well-documented through history and in many regions of the world. Localized knowledge sharing was common among employees of geographically clustered firms in the steel industry in nineteenth century England (Allen 1983). Case studies of regional clusters of small and medium sized firms in Italy (Piore and Sabel, 1984) and Baden-Wuerttemberg in Germany (Herrigel, 1993) indicate that social communities play an important role in knowledge exchange across the firms located in these regions. In a seminal study, Annalee Saxenian (1994) carried out an ethnography of engineers in Silicon Valley (south of San Francisco) and Route 128 (which encircles Boston), and attributed the success of the former to a more robust exchange of knowledge among people and firms in the Valley. An idea for a new product or process may originate from individuals or small groups within or outside a firm. The development of ideas into an innovative product or process requires the combination of knowledge from several perspectives. This development of ideas is facilitated by face-to-face discussion and knowledge sharing by players within social communities in the region. The common thread in all these studies is the role played by social communities in facilitating the flow of knowledge between individuals within a geographic region. The knowledge exchanged is relevant to various parts of economic success – including production, marketing, and new venture creation and, especially, innovation (Porter 2000, Rogers, 1983).

In addition to geographically mediated social communities, engineers and scientists belong to professional communities that often span regions and countries. In early work in this area, Diana Crane (1972) describes how the ‘invisible college of scientists’ helps diffuse knowledge within scientific communities beyond the boundaries of a firm. These scientists are seen to belong to a social community of researchers and inventors that is bounded, not by geography or organizations, but rather by common scientific and technological interest. Rappa and Debackere (1992) explain that conversations between experts within technological communities (and across firms) also result in the sharing of information and know-how that is of common interest to members of the group. Of course, with the advent of the internet and international travel, these technological communities can take on an international character. Ethnographic research on web-based communities (Madanmohan and Navelkar, 2004) describes how the internet facilitates the exchange of knowledge across individuals in distant locations. This individual-level exchange of knowledge can be particularly important in knowledge intensive industries like semiconductors and biotechnology. Research has highlighted the role played by collaborations between star scientists in universities and firms (Song et. al., 2003; Zucker, Darby and Torero, 2002) and the importance of communities of practice in sharing non-local knowledge (Gittelman, 2007). These communities have a strong social dimension (common language and norms) that governs the flow of knowledge between researchers (Knorr-Cetina, 1999). Scientists in biotechnology firms can use these social communities to develop links to other scientists in firms, universities, and research institutions and these links act as informal bridges across firm and geographic boundaries (Allen and Cohen, 1969). Thus, scientists simultaneously belong to organizational and technological communities (Brown and Duguid, 2001) and often facilitate the flow of knowledge between these networks.

Indian immigrant inventors in the semiconductor industry (like others in their field) have the opportunity to access and use knowledge from geographic and technological communities. Prior research suggests that participants use geographic and technological communities to enhance their economic well-being, including to access knowledge associated with innovation. For instance, Powell and Smith-Doerr (2005) describe how individuals and groups in biotechnology firms use informal collaborations to access knowledge from other institutions including firms, universities and government laboratories to enhance their own innovativeness and that of their groups. These researchers chose partners depending on the problem they are tackling and the complimentary expertise they are seeking. Scientists may develop lists of possible collaboration partners based on their knowledge expertise and contact them to help solve the problem at hand.

Rogers (1983) describes how semiconductors engineers in Silicon Valley meet in social settings like the Wagon Wheel Bar to share job and work related information useful to their careers and research. Knowledge is the currency that permits membership in these geographically and technologically mediated social groups and receiving and providing knowledge is an expectation. Therefore, the motivation to join and participate in these communities appears to be instrumental - based on a rational expectation of reciprocity in giving and receiving useful, often technological, knowledge.

Another interesting factor about the geographic and technological communities is that membership can, and does, change over time. Almeida and Kogut (1999), in their study of semiconductor engineers, show that mobility of engineers and across both geographic regions and between firms within a region is commonplace. This movement of people across communities is likely to create flexibility and broaden the scope of professional or geographic influences on their innovation. Given this mobility, innovators are less likely to become over-embedded in one social community or get locked into a community over time.

We expect the advantages of social and geographic communities to enhance the innovativeness of the participants. The downsides of social communities (potential lock-in and overembeddedness) are likely to be minimal given the flexible and dynamic nature of technological and geographic communities. Therefore, Indian inventors are likely to draw knowledge from these communities when it is useful to them and use this knowledge to enhance their innovativeness.

Hypothesis 1A: For Indian immigrant inventors, greater emphasis on knowledge from geographic communities results in an increase in their innovativeness.

Hypothesis 1B: For Indian immigrant inventors, greater emphasis on knowledge from technological communities results in an increase in their innovativeness.

Ethnic Communities and Innovation

Aldrich and Waldinger (1990) describe an ethnic community as having members of common culture and origin who are aware of their membership in a group. Ethnic social communities confer the benefits of social interaction, common value systems, and trust based relationships that facilitate social cohesion that can enhance the economic success of its members (Iyer and Shapiro, 1999; Tsai and Ghoshal, 1998). One well-researched area in economic sociology is the entrepreneurial role played by ethnic groups (Greene and Butler, 1996). In technology intensive industries, scholars point to the role of ethnic communities, in facilitating not just entrepreneurship, but also innovation (Saxenian and Hsu, 2001). Saxenian (2002) believes that ethnic communities offer a flexible mechanism for transferring knowledge between participants even across distant regions. Similar to arguments made by Light (1984), she posits that immigrants view themselves as outsiders to the mainstream technology community and consequently foreign-born engineers and scientists forge social relationships based on their national identity that enable the exchange of information and know-how. This would suggest that reliance on ethnic communities should enhance an individual's innovativeness.

Reliance on an ethnic community could be a double-edged sword. Portes (1998) suggests that the sense of altruism is especially strong in ethnic communities and helps bind community members together but this could lead to over-reliance on community sources of knowledge. Karra et. al. (2005), in their case study of Balkan immigrant communities, find that the strong sense of solidarity in the community does lead to overembeddedness. Individuals are tied so strongly to the expectations of others in the community that their relationships with other non-ethnics are constrained (Bowles and Gintis, 2004) and they are often unable to break away form these constraints. Another reason why ethnic communities may stifle innovation is that they could present lack of diversity within the community and offer the same set of skills and approaches, resources, and competences that could be redundant. Portes (1998) cites the example of the narrow lines of business practiced by San Francisco's ethnic Chinese community to suggest that in many cases ethnic communities force solidarity on their members and the current practices and ways of thinking stifle the availability of new knowledge. This solidarity could take place to the extent to which an individual's ability to innovate or seek new ways of doing things is suppressed.

Similar to the idea of path dependence in evolutionary economics, sociologists since Becker and Granovetter have referred to the idea of cumulative causation whereby historical decisions and actions determine future possibilities. Of course community norms and expectations can play a role in forming and directing the actions of individuals along particular paths. Waldinger (1994) attributes the dominance of Egyptian and Indian engineers in the New York City bureaucracy to cumulative causation where historical actions by early community members lead others to view possibilities and opportunities through a narrow historical lens. This leads to a continued reliance on community knowledge and ideas even when opportunities elsewhere may exist. The case study by Karra et. al. (2006) suggests that this can lead to lock –in. They observed that individuals influenced by habit, social expectations, and limited worldviews continued to be a part of the ethnic community long after they played a constructive role or after it was useful.

We argue here that Indian immigrant inventors (like other ethnic groups) belong to social communities influenced, in part, by altruistic motives associated with shared values and a sense of common identity with other Indians. In these, as in other ethnic communities, altruistic motivations may allow the negative aspects of social capital such as over-embeddedness and lock-in to kick in. While some Indians may be more loosely tied to the ethnic community (and thus source knowledge in a more rational manner) others may be more deeply embedded. This could lead the more deeply embedded individuals to both share knowledge and source knowledge even when this is not aligned with their economic incentives and does not enhance their innovativeness. It also suggests they may utilize knowledge from ethnic communities even when this may not be useful.

Hypothesis 2: For Indian immigrant inventors, the relationship between knowledge emphasis on ethnic communities and inventor innovativeness is characterized by an inverted U.

Geographic and Organizational Mobility and Innovation

We have argued that immigrants may sometimes be overly influenced by knowledge available in their ethnic social communities. Immigrant engineers could potentially mitigate this limitation by exposing themselves to knowledge influences beyond their ethnic community. Studies on the mobility of engineers and scientists (Almeida and Kogut, 1999; Hoisl, 2007) highlight the important role that the movement of inventors across geographic regions and organizations can play in both transferring knowledge across regions and absorbing new knowledge and hence enhancing inventor productivity. Mobile inventors are exposed to new ideas, ways of thinking, and know-how that may be embedded within organizations or geographic regions and that may not be otherwise observable or salient across organizational and geographic boundaries. Mobility allows them to absorb and utilize additional knowledge that can enhance their innovativeness. These ideas are borne out by studies on ethnic groups that suggest that movement beyond the confines of the ethnic community, though sometimes difficult (Bowles and Gintis, 2004), can reduce the reliance on knowledge from within the group and enhance the availability of new and unique knowledge to the individuals. Hence, we expect that mobile Indian immigrant inventors will have an enhanced capacity to identify, access, and use knowledge relevant to the innovativeness.

Hypothesis 3A: For Indian immigrant inventors, greater inter-organizational mobility results in an increase in their innovativeness.

Hypothesis 3B: For Indian immigrant inventors, greater inter-regional mobility results in an increase in their innovativeness.

DATA AND METHODS

We test our hypotheses by examining the knowledge sourcing patterns of inventors of Indian origin working in the U.S. semiconductor industry. In this paper we use patent data[2] to identify Indian inventors, to determine

[2] A patent is the grant of a property right to an inventor for an invention conferred by the government. It establishes the "right to exclude others from making, using or selling the invention" for a period of up to 20 years. A U.S. patent is granted for an invention that is

their innovativeness, to measure these inventors' utilization of different social communities, and to capture their mobility patterns. Our sample consists of every identifiable Indian inventor with a U.S. location who was granted a semiconductor patent in 1999[3]. To construct our sample, we first used the NBER database of U.S Patent and Trademark Office (USPTO) patents, and identified 18,300 semiconductor patents with 41,930 distinct inventors. Two individuals of Indian origin then examined every patent and using the inventor names (first, middle and last)[4] compiled a sample of 342 Indian inventors[5]. To evaluate our approach, we obtained the resumes of 50 of the most productive inventors (convenience sample) to verify if they were, in fact, Indian immigrants. The resumes of every inventor showed that every inventor identified was an immigrant Indian who was now working in the US. After identifying the Indian inventors, we traced the patenting records of each inventor over a 10 year period from 1990 to 1999 and identified a total of 2284 patents[6]. The unit of analysis in our sample is an inventor-year. Each of the 342 Indian inventors was tracked over the 10-

'useful', 'novel' and 'non-obvious to a person of ordinary skill in the art' (U.S. Department of Commerce, 1992).

[3] We used the grant date to identify patents filed by Indian inventors since only granted patents can potentially bring commercial value for assignee firms and thus be considered an innovation. The application dates for these patents ranged from 1994 to 1999. We used 1999 as the focal year to compose our sample since it is the most recent year available in our data source (National Bureau of Economic Research).

[4] Using first, middle and last names enables the identification of individuals with common last names. For e.g , our sample has multiple patents by inventors with the last name Singh. Since almost all inventors in our sample consistently patented using first and middle names in addition to last names, we were able to identify, Abha R. Singh, Akhileshwar R. Singh, Gajendra P. Singh, Rajendra Singh and Ranbir Singh as five different individuals.

[5] Indians belonging to the Hindu religion comprise about 84% of the Indian population and their names are largely unique to India. India also has a significant percentage of Muslims and Christians whose names are not unique to India. Our approach did not allow us to identify these Indians. The two coders of Indian origin assessed all names, if they did not agree in their assessment, we did not include the inventor name in our sample

[6] In the process of tracing patenting records of our Indian inventors, we were cognizant of the potential "who is who" problem noted by Traitenberg, Shiff and Melamed (2006)— the name of a given inventor may be spelled differently across his/her patents or the same name may correspond to different inventors (the "John Smith" problem). We believe that the "who is who" problem is attenuated for Indian inventors largely due to the uniqueness of Indian names. However we ran several checks. First, we checked first, middle (where available) and last names to ensure an accurate matching. Second, we took additional steps to ensure that each of the 342 inventors identified were unique and detail the process utilized for unique assignment in Appendix 2. Third, we used the resumes of the 50 most productive Indian inventors from our sample and compared the information obtained from this source with that obtained from the patent database. We found a 100% match.

year period (1990-1999), bringing the total number of observations in the sample to 962[7].

Patent documents provide data on the inventor, firm, geographic location and technology of the invention, and also the scientific and technological influences on the innovation. As in previous studies using patent citation data (Rosenkopf and Almeida, 2004), we use the name of the first inventor of a patent to identify the inventor and the geographic location of the invention and the date of application of the patent to establish the innovation date. The list of patent citations, provided on the front page of the patent document, permits us to infer the scientific and technological influences on a particular invention (Jaffe et al, 1993). The patent applicant is obliged by law to specify in the application any and all of 'the prior art' of which the applicant is aware. The list of citations for each patent is established through a uniform and rigorous process applied by the patent examiner as a representative of the patent office (Albert et al, 1991). We use the list of citations on a given patent to gauge the knowledge sources that influenced an inventor when developing his or her innovation. We therefore rely on patent citations as a proxy measure for assessing the knowledge exchange outcomes of geographic, technological and ethnic communities.

There are, of course, a number of limitations to using patent data to capture innovation and knowledge emphasis. First, patents reflect codified knowledge but not tacit knowledge (such as that embedded in organizational routines). Therefore patents may only be a partial measure of the innovativeness of an inventor. However, Mowery, Oxley & Silverman, (1996) point out that codified knowledge flows (represented by patents) and tacit knowledge flows are closely linked and complementary. Another potential drawback in the use of patent data is that patenting is itself a strategic choice and hence all technological innovations may not be patented. However, the nature of competition in the semiconductor industry encourages active patenting of innovations. This is particularly true at the individual inventor level, Almeida (1996) in his interviews with head-hunting

[7] The actual sample size of 962 is different from 342 (number of Indian inventors) multiplied by 10 (number of years), 3420 because not all inventors patented in all 10 years.

firms and engineers found that patents are valuable to individual engineers and researchers in this industry as indicators of personal technological expertise. A third issue is that we rely on patent citations as a proxy measure for inferring the knowledge exchange of geographic, technological and ethnic communities. Despite some limitations associated with the use of patent citation data, the uniformity and availability of the data has led to their increasing use in management research (Jaffe, Fogarty and Banks, 1998; Jaffe, Trajtenberg and Henderson, 1993).

Dependent variable

Innovativeness of Indian inventors – The dependent variable is measured in two ways. First, we measured *quantity* of innovation as the number of semiconductor patents filed by the Indian inventor in a given year 't'. We used the patent application date of successful patents (or the date that patent was filed with the Patent Office) to indicate the year of innovation. Our second measure of innovativeness is the *quality* of patents produced by the Indian inventor. The number of subsequent citations received by a patent is a good proxy for its quality since it demonstrates the importance of an innovation and its potential economic value (Trajtenberg, 1990; Gittelman and Kogut, 2003). To construct this measure, we first considered all semiconductor patents filed by an inventor in year 't'. We then computed the total number of citations received by these patents within 6 years[8] of year 't'. We did not include self-citations by the inventor. Our measure provides an assessment of quality external to, and independent of, the inventor. We then calculated quality as the total number of citations for the year 't'.

Independent variables

To construct our independent variables, we created a comprehensive historical patent record for each Indian inventor by examining all patents filed by the inventors from 1975 to 1999. We then used patent information related to citations, assignee firms, technology class, inventor location and year of application to construct our measures.

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[8] Typically, five years is the duration of a product life cycle in the semiconductor industry (Stuart & Podolny, 1996) and therefore allowing for a six year period for citations should provide an accurate reflection of the importance of the patent.

Knowledge from geographic, technological and ethnic communities:

To measure the knowledge influences of the various social communities we considered the inventor's patent portfolio in year 't'. We then examined the patents cited [9] by this portfolio in the six years[10] prior to the year considered. Cited patents were created prior to year t (in contrast to the *citing* patents used to measure quality that are filed after year t) and had application years from year 't-6' to 't'**.** The cited patents identify the technological antecedents of the innovation and reflect the knowledge utilized to create innovation. We then classified the cited patents (and their inventors) as belonging to the various communities in the year 't' as follows. A cited patent (and its inventor) are deemed to belong to the same geographic community as that of the Indian inventor if the two patents are from the same US state (as indicated by each inventors' location). A cited patent (and its inventor) are deemed to belong to the same technological community of the Indian inventor if the two patents belong to the same three digit technology class in the semiconductor industry. A cited patent (and inventor) are seen to belong to the ethnic community, if the cited inventor has an Indian name. These three communities are not mutually exclusive since a cited patent could belong to more than one category. The number of citations to each community gives us the numerator for each of our variables However, the number of citations to a particular community (for e.g. geographic community) by an Indian inventor may reflect the preponderance of knowledge in the community rather than the extent to which the inventor relies on the community for his or her knowledge. When considering geographic communities, to control for the differences in availability of relevant knowledge across states (and across time) we divided the numerator (the total number of citations by the Indian inventor to in-state inventors) by the total number of patents filed by all inventors in that state for years t-6 to year t. The resultant variable measures the propensity of the Indian inventor to source knowledge locally and hence gives us a measure of the emphasis placed by the focal Indian inventor on knowledge from the geographic community. The higher the value of the

[9] Self citations by the inventor are not included in the cited patents
[10] The basis for a six year period is similar to that considered for citing patents since it reflects life cycle in the industry and the life of knowledge.

variable, the greater is the emphasis that the Indian inventor placed on knowledge from his geographic community. Similarly, we calculated the knowledge emphasis placed by an Indian engineer in a particular year on the technological community by dividing the total cites (by the engineer's patent portfolio in a given year) to other patents (between years t and t-6) in a semiconductor technology class, by the total number of patents (whether cited or not) applied for in that time period and in the same semiconductor technology classes. Finally, we calculate the knowledge emphasis placed by an Indian engineer on their ethnic community by dividing the total cites (by the engineer's patent portfolio in a given year) to other patents (between years t and t-6) created by other Indian engineers (regardless of technology or location), by the estimated total number of patents (whether cited or not) applied for in that time period by Indian engineers[11].

Mobility We constructed mobility measures by examining the inventor's geographic and firm location (for each patent) and comparing this across time[12].

[11] The denominator for the total pool of knowledge of Indian inventors is difficult to determine (due to the need to manually identify Indian inventors across millions of patents). We estimated this pool for each year. To build the estimate we first determined Indian inventor patents as a percentage of total semiconductor patents filed in 1999. This percentage was 4.75%. We then obtained from the database the total population of semiconductor patents filed in each year up to 1999. Assuming semiconductor patents filed by Indians were constant at 4.75%, we obtained a preliminary estimate of Indian inventor patents in each year. Since this estimate does not take into account the possible growth or decline in the population of Indian semiconductor inventors, we turned to U.S. census data to calculate an index of Indian population growth in the US from 1984 to 1999 (compared to the growth of the US population). We applied this index of growth in population to our preliminary estimate to arrive at the final estimate of population of Indian inventor patents in a particular year.

[12] Since we rely on patenting records to estimate organizational and geographic mobility our measures may underestimate inventor mobility. This is particularly true if an inventor moves to a different organization or location but does not file a patent. However given the pervasive nature of patenting in this industry, the underestimation is likely to be minimal.

Organizational mobility: This measure reflects inventor movement across different organizations. It is a count of the number of firms, indicated as assignees of the patents filed by an Indian inventor from 1975 to year t.

Geographic mobility is used to assess inventor movement across different geographic regions. It is measured as the number of different inventor locations (states), indicated on the patents filed by the inventor from 1975 to the year t.

Controls: Our model incorporates various individual inventor and firm controls that are expected to have an effect on the innovativeness of the Indian inventor.

Knowledge from Organizational Community: Organizations offer inventors significant resources and knowledge access to support their innovative agendas. We therefore control for the amount of knowledge utilized from the inventor's firm (or organizational community). The numerator of this variable was calculated as the number of patents cited (with application dates between t-6 to year t) by the Indian inventor's patent portfolio in year t, whose assignee firm was the same as that of the Indian inventor in year t. The denominator is the total population of patents assigned to the firm of the Indian inventor from year t-6 to year t. *Inventor experience* permits the creation of a broader knowledge base and better capabilities to produce innovation**.** We measured inventor experience as the number of years between the year of application of the first patent filed by the inventor and the year t. *Collaborators* on a patent provide another avenue to increase innovation quality by sharing and combining distinct insights of various inventors**.** To measure this variable, we used a count of the co-inventors indicated on the patent portfolio of the Indian inventor in year t. We also assessed the impact of *Inventor order.* For patents with multiple inventors, we controlled for the order of authorship to assess the relative contribution of the Indian inventor relative to his/her collaborators.

We also controlled for firm characteristics that may affect innovation. We used the length of the firm's patenting experience as a proxy for *firm age*. Firms with a long history of patenting are more likely to have developed routines and norms to better guide their inventors to produce innovations. We traced the patenting history of all our sample firms in

USPTO database to find their earliest patent application year. We calculated firm age as the difference between year t and the application year of the first patent filed by the firm. We used a binary variable to indicate whether an assignee firm is a *public or a private firm.* Firms that are publicly traded are more likely to have access to capital and resources. Therefore, we expect public firms to provide a more supportive environment for inventors. To code this binary variable, we checked each of our sample firms to see if they were listed on the New York Stock Exchange—if yes, this variable is coded as 1; otherwise, as 0. Firms with a rich stock of patents are likely to have a broader knowledge base and better capabilities, which inventors can draw from We measured a *firm's knowledge base* as the number of patents filed by the inventor's firm from year t-6 to t.

In addition, to overcome possible issues of heteroscedasticity and first-order autocorrelation associated with our longitudinal sample, we control for the *lagged inventor quantity and quality*, measured at year t-1 in our regressions.

Our dependent variables, innovation quantity and quality, are count variables and take on only non-negative integer values. Studies involving patents and their citations pose a number of econometric and measurement issues, that primarily stem from the count nature of the dependent variable (Hausman, Hall & Griliches, 1984). We follow the approach suggested by Hausman, et al (1984) in their analysis of patent data and other researchers when dealing with event count data (Kogut & Chang, 1991) using the negative binomial regression model. We have panel data involving repeated observations of our set of Indian inventors over time, so there may be certain unaccounted inventor effects and year effects that are fixed or vary randomly. Fixed effects and random effects models allow us to control for these effects. We present our results with a random effects specification[13].

Findings

Appendix 1 presents the summary statistics for our sample. The Indian inventors in our sample produced a yearly average of 2.46 patents; their

[13] The nature of our sample is such that some of the Indian inventors in our sample contribute only a single year of observation. Running a fixed effects specification in STATA causes the package to automatically drop all the single year observations. Therefore we used the random effects specification.

annual patent portfolios received on average 23.86 citations. This suggests that a single patent filed by the Indian inventor was received just under 10 citations per patents. Semiconductor industry patents received an average of 10 citations in 1992 (Kim, Lee, Marschke, 2006) suggesting that our sample average for quality of immigrant inventors is close to the industry average. The emphasis on the various communities reveals an interesting contrast. First, not surprisingly, inventors draw most of their knowledge from within their own organization. Intra-organizational communities may be more conducive to knowledge sharing due to the organizational mechanisms that facilitate knowledge flows. The data shows that inventors draw upon knowledge from technological communities and, to a lesser extent, from geographic and ethnic communities.

To test whether inventors in our sample draw knowledge from their ethnic (Indian) community more than non-Indian inventors do, we conducted an additional test. We created a control group of non-Indian inventors with patents (matched on location and technology class to our original sample) and compared knowledge cited by these patents to those from the Indian sample. We found that the Indian inventors cited other Indians significantly more than the control group, indicating that membership in the Indian ethnic community leads to an increase in the amount of knowledge sourced from within the community.

Indian inventors tend to demonstrate limited mobility and have typically not moved between organizations. The average of 1.07 moves per inventor reflects that the typical inventor has made only one inter-organizational move. Geographic mobility represents a similar trend with an even lower average of 0.86. Indian inventors typically tend to move across states only once. Our inventors had an average patenting experience of 4.68 years and these inventors worked for mostly public firms that were on average 23 years old and had large patent portfolios.

We measured innovativeness of the Indian inventor by the quality and quantity of patents produced by them in a given year. We present our findings on quality in Table 1 and quantity in Table 2.

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Insert Tables 1 and 2 here

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Table 1 presents five regression models. Model 1 is our baseline model with the control variables, models 2-4 introduce the independent variables, and Model 5 is the comprehensive model. The results suggest that the addition of the independent variables significantly increases the explanatory power of the model (Wald Chi-squared increasing from 476.50 in Model 1 to 696.34 in Model 5). Results from our baseline model (model 1) point to the importance of collaborators, the public status of the firm, and the prior quality of patents produced by the inventor in influencing the quality of innovation of the Indian inventor. We find partial support for Hypothesis 1A – knowledge emphasis on the geographic community is not significant in Model 2, but is positive and significant in the comprehensive Model. Hypothesis 1B receives strong support – emphasizing knowledge from the technological community enhances the quality of innovations produced. The effects of the ethnic community on innovativeness are as predicted – Hypothesis 2 is supported. We find evidence of an inverted U relationship between emphasizing knowledge from the ethnic community and the quality of innovation. An evaluation of the coefficients suggests that a majority of the innovators draw knowledge from the ethnic network at levels that result in positive effects on their innovation. We find support for the positive effects of inter-regional mobility (Hypothesis 3B). However, the hypothesis regarding inter-organizational mobility (Hypothesis 3A) is not supported. It seems to be necessary to move across state boundaries rather than organizational boundaries to gain new knowledge that will result in higher quality of innovation.

Table 2 presents our results for the regressions with the dependent variable measuring the number (or quantity) of innovations. Model 6 is the baseline model with the control variables, models 7-9 introduce the independent variables, and Model 10 is the comprehensive model. Similar to our findings on quality, the addition of our independent variables increases the explanatory power of our model (Wald Chi-squared increasing from 677.96 in Model 1 to 2334.78 in Model 5). Results from our baseline model

(model 5) highlight the importance of inventor experience, collaborators, and the public status of the firm. Our findings for innovation quantity largely mirror the results for innovation quality. Emphasizing knowledge from geographic and technological communities increases the number of patents produced (Models 7 and 10). The effects of the geographic community are more consistent in this set of findings. The inverted U effect of the ethnic community is also supported for innovation quantity. We see an interesting divergence in the effects of mobility. Inter-organizational mobility has a significant and positive impact on the quantity of patents produced (in contrast to the lack of significant effects for quality). Inter-regional mobility, which was significant for innovation quality, is not significant for innovation quantity. Perhaps this result may be driven by the fact that organizations provide access to knowledge that may be largely redundant enabling inventors to create new patents but of lower quality. On the other hand geographic mobility enables access to new insights (that may be harder to integrate and utilize) therefore increasing quality but not necessarily the quantity of patents.

An interesting question is whether experienced inventors in the Indian community experience lock-in or whether they reduce emphasis on ethnic community knowledge over time. To investigate this, we split our sample into three sub-samples, based on inventor experience (with patenting) – less experienced inventors, moderately experienced inventors and more experienced inventors. Inventors in our sample had patenting experience ranging from 0 years (indicating a first patent filing) to 24 years, with an average of 4.68 years. Those with less than two years of experience were classified as less experienced inventors, those with between two and six years of experience were classified as moderately experienced inventors and those with more than six years of experience as more experienced inventors. We ran regressions for these three categories of innovators and our findings are presented in Tables 3 and 4.

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Insert Tables 3 and 4 here

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The results for both quality and quantity of innovation suggest that the effects of the ethnic community become negative with experience. We observe an inverted U relationship between knowledge emphasis and innovativeness for less experienced inventors. However the negative effects set in only with a substantial emphasis of knowledge as indicated by the coefficients of the squared terms in Models 11 and 14. These negative effects set in quicker for the moderately experienced inventors (Models 12 and 15). As for the most experienced inventors, there are only negative effects of knowledge emphasis on the ethnic community for quality (Model 13), while an inverted U is observed for quantity (Model 15). It appears that for less experienced inventors, ethnic communities may be useful sources of knowledge to enhance their innovativeness and economic activity, but their usefulness may decrease with experience and time. Lock-in of more established members of the ethnic community suggests that they emphasize knowledge sharing within the community even when it may not be useful to them anymore. Therefore the negative effects of lock-in for the ethnic community appear to be limited to quality of innovation.

DISCUSSION AND CONCLUSIONS

Our study has several limitations that present opportunities for future research. We focus on one community, Indian inventors in the U.S and our results cannot be generalized to all immigrant inventors. An interesting extension would be to explore other ethnic communities and examine if they demonstrate similar innovation patterns. Our sample consists of inventors identified as Indian immigrants on the basis of their first and last names. However, except for a small subsample, we do not have information documenting these individuals as immigrants. Our use of patents to trace mobility is in accordance with prior studies but may result in an omission of companies (or locations) where the inventor was hired but did not produce a patent. Our study suggests that inventors place different levels of emphases on each of the communities considered. We plan to conduct future research to explore whether inventors balance the emphases across communities and are able to offset limited emphasis on one community with greater emphasis on another.

This paper attempts to contribute to our understanding of social communities and innovation in several ways. First, there has been significant theoretical and empirical research on social communities including the implications of these communities on innovation (Adler and Kwon, 2002; Dyer and Noboeka, 2000; Saxenian, 1994; Rappa and Debackere, 1992). Our study makes a contribution along these lines and illustrates the importance of social communities and mobility for immigrant inventor innovativeness. Our findings suggest that Indian inventors tend to successfully draw upon knowledge from technological and geographic communities. This substantiates the view that social communities offer benefits (Coleman, 1988) through access to knowledge resources. It complements research that suggests social communities influence individual level outcomes (Podolny and Baron, 1997; Rodan and Galunic, 2004).

This research builds on the previous studies by examining the simultaneous effects of three sets of communities on an individual's innovativeness. Most individuals belong to several (often overlapping) communities. Looking at an individual's membership of a single community in isolation may present an incomplete or even misleading picture of the role of the community in influencing an individual's behavior and actions. When we model the impact of three social communities together we can get a clearer view of the influences on, and the results of, each community on the individual's innovative actions. As expected from previous research, all three – technological, geographic and ethnic - communities matter, but this study shows that they affect innovativeness in different ways. Geographic and technological communities appear to enhance an individual's innovativeness, while ethnic communities may not always do so. Further, knowledge sourced from technological communities appears to enhance both the quality and quantity of innovation, while geographic communities appear to have a strong effect primarily on the number of innovations.

Another idea suggested by this study is that ethnic communities may be less dynamic in nature than technological or geographic communities. Members of ethnic communities appear to continue to engage in knowledge sharing even when the economic benefits to them are not positive. Though we do not observe this directly, this finding can be explained by the altruistic motivation for community participation. On the other hand, our findings suggest that technological and geographic communities may be more dynamic and members engage in knowledge sharing driven by rational motivations. Our findings on the positive effects of knowledge sourced from these communities on innovation are aligned with this explanation. Hence ethnic communities may differ from other social communities not just in terms of their structure but in terms of the motivations for belonging and sharing knowledge.

Recent literature on communities highlights the important role they play in sharing knowledge across their members. This is often seen as a positive aspect of membership. A question we often do not ask is, "Is more knowledge necessarily better?" While membership in a community, and the social capital this facilitates, often provides individuals with access to more knowledge, this paper highlights the fact that knowledge may not always be useful. An associated contribution this paper attempts to make is distinguishing between merely accessing knowledge and effectively accessing and utilizing knowledge to enhance innovativeness. Especially in a dynamic and evolving industry like semiconductors, access to the novel and cutting edge knowledge and information may be the critical ingredient for success and not every community relationship can provide this.

The growing body of research documenting the importance of the immigrant community to the U.S economy (Kerr, 2008; Florida, 2004; Saxenian, 1999) suggests an imperative for research examining immigrant inventor innovativeness. Our study points to the role played by ethnic communities in shaping immigrant Indian inventor innovation. It complements the existing literature on ethnic communities (Kalnins and Chung, 2006; Rauch and Trinidade, 2002) by formally examining the effects of the ethnic community membership on knowledge and innovation. The effects of the ethnic community present a marked contrast to the technological and geographic communities. Knowledge from ethnic community can be useful for inventors – provided they do not become over-dependent on this knowledge. The relevance of the immigrant community as a source of knowledge useful to innovation suggests that culture and joint heritage continue to endure after migration and significantly influence economic exchanges. However, there is a danger of over-embeddedness that is detrimental to the innovator. Our findings on ethnic communities draw attention to the potential benefits and costs associated with belonging to these social communities.

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Table 1 – Knowledge emphasis and innovativeness (quality) of Indian inventor

Dependent variable – Innovativeness of Indian Inventor (Quality)

Independent variables		**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Geographic community emphasis	**H1A**		3.98 (3.52)			7.78* (3.84)
Technological community emphasis	**H1B**		4.08*** (0.76)			4.52*** (1.31)
Ethnic community emphasis	**H2**			123.19*** (13.28)		80.44*** (17.00)
Ethnic community emphasis squared	**H2**			-4104.20*** (374.75)		-3274.90*** (423.87)
Inter-organizational mobility	**H3A**				0.007 (0.02)	0.005 (0.02)
Inter-regional mobility	**H3B**				0.06** (0.02)	0.04* (0.02)
Controls						
Organizational community emphasis		0.07 (0.06)	0.06 (0.06)	0.002 (0.05)	0.09 (0.06)	0.0002 (0.05)
Inventor experience		0.008 (0.006)	0.009 (0.005)	0.009 (0.006)	-0.0005 (0.006)	0.005 (0.006)
Collaborators		0.03*** (0.001)	0.03*** (0.002)	0.03*** (0.002)	0.03*** (0.002)	0.04*** (0.002)
Inventor order		-0.03 (0.03)	-0.03 (0.03)	-0.05 (0.03)	-0.05 (0.03)	-0.07* (0.03)
Firm age		-0.005 (0.003)	-0.004 (0.003)	-0.003 (0.003)	-0.005 (0.003)	-0.002 (0.002)
Firm public		0.23** (0.08)	0.20** (0.08)	0.18* (0.08)	0.24** (0.08)	0.16* (0.07)
Firm knowledge base		0.00001 (0.00001)	0.00001 (0.00001)	0.000001 (0.00001)	0.00001 (0.00001)	0.000001 (0.00001)
Lagged inventor quality		0.002*** (0.0006)	0.001** (0.0007)	0.001* (0.0005)	0.001* (0.0006)	0.001 (0.0006)
Wald Chisquared		476.50***	526.78***	647.54***	491.80***	696.34***

Standard errors in parentheses
* p<0.05, **p<0.01, ***p<0.001
N =962

Table 2 – Knowledge emphasis and innovativeness (quantity) of Indian inventor

Dependent variable – Innovativeness of Indian Inventor (Quantity)

Independent variables		**Model 6**	**Model 7**	**Model 8**	**Model 9**	**Model 10**
Geographic community emphasis	**H1A**		7.35** (2.33)			6.97*** (2.17)
Technological community emphasis	**H1B**		3.02*** (0.69)			3.77*** (0.72)
Ethnic community emphasis	**H2**			116.49*** (9.87)		66.69*** (12.30)
Ethnic community emphasis Squared	**H2**			-3386.30*** (268.43)		-2689.45*** (276.46)
Inter-organizational mobility	**H3A**				0.05** (0.01)	0.03* (0.01)
Inter-regional mobility	**H3B**				0.01 (0.01)	0.01 (0.01)
Controls						
Organizational community emphasis		0.08 (0.04)	0.07 (0.04)	0.03 (0.04)	0.11* (0.04)	0.009 (0.04)
Inventor experience		0.01** (0.005)	0.01** (0.004)	0.01** (0.004)	0.004 (0.005)	0.01* (0.004)
Collaborators		0.04*** (0.002)	0.04*** (0.002)	0.04*** (0.001)	0.04*** (0.002)	0.04*** (0.001)
Inventor order		-0.04 (0.03)	-0.03 (0.03)	-0.05 (0.03)	-0.05 (0.03)	-0.08** (0.03)
Firm age		-0.003 (0.002)	-0.002 (0.002)	-0.001 (0.002)	-0.003 (0.002)	-0.0002 (0.002)
Firm public		0.11@ (0.06)	0.06 (0.06)	0.07 (0.06)	0.18** (0.06)	0.06 (0.06)
Firm knowledge base		0.0000 (0.00001)	0.0000 (0.00001)	0.00001 (0.000009)	0.0000 (0.00001)	-0.00001 (0.000001)
Lagged inventor quantity		0.001 (0.006)	0.001 (0.006)	-0.004 (0.005)	-0.007 (0.0006)	-0.002 (0.005)
Wald Chisquared		677.96***	818.10***	1349.37***	770.77***	2334.78***

Standard errors in parentheses
* p<0.05, **p<0.01, ***p<0.001
N =962

Table 3 – Experience effects and innovativeness (quality) of Indian inventor

Dependent variable – Innovativeness of Indian Inventor (Quality)

Independent variables		**Model 11 Less experienced Inventors (Less than 2 years of experience)**	**Model 12 Moderately experienced Inventors (Between 2-6 years of experience)**	**Model 13 More experienced Inventors (More than 6 years of experience)**
Geographic community emphasis	H1A	14.64 (12.43)	6.21 (5.81)	5.38 (8.86)
Technological community emphasis	H1B	-4.39 (3.53)	3.41 (1.96)	10.94*** (2.42)
Ethnic community emphasis	H2	216.12*** (57.14)	118.55*** (27.78)	31.26 (28.98)
Ethnic community emphasis squared	H2	-15055.66*** (4364.11)	-4176.43*** (784.16)	-2569.78*** (579.05)
Inter-organizational mobility	H3A	0.19 (0.13)	-0.02 (0.04)	0.04 (0.03)
Inter-regional mobility	H3B	0.16 (0.14)	0.04 (0.04)	0.03 (0.03)
Controls				
Organizational community emphasis		0.15 (0.14)	0.02 (0.11)	0.03 (0.07)
Inventor experience		OMITTED	OMITTED	OMITTED
Collaborators		0.04*** (0.007)	0.04*** (0.004)	0.04*** (0.007)
Inventor order		0.04 (0.06)	-0.18*** (0.05)	-0.07 (0.06)
Firm age		-0.003 (0.004)	0.007 (0.004)	-0.01** (0.005)
Firm public		0.24 (0.13)	-0.06 (0.14)	0.39** (0.13)
Firm knowledge base		-0.00001 (0.00001)	0.00001 (0.00002)	0.00003 (0.00002)
Lagged inventor quality		0.002 (0.005)	0.0004 (0.001)	-0.0003 (0.002)
Wald Chisquared		219.63***	276.17***	247.98***
N		375	316	271

Standard errors in parentheses

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 4– Experience effects and innovativeness (quantity) of Indian inventor

Dependent variable – Innovativeness of Indian Inventor (Quantity)

Independent variables		**Model 14 Less experienced Inventors (Less than 2 years of experience)**	**Model 15 Moderately experienced Inventors (Between 2-6 years of experience)**	**Model 16 More experienced Inventors (More than 6 years of experience)**
Geographic community emphasis	H1A	-11.49 (8.96)	-3.99 (4.13)	4.04 (5.85)
Technological community emphasis	H1B	0.63 (2.66)	-0.06 (1.30)	5.44*** (1.34)
Ethnic community emphasis	H2	244.52*** (48.62)	89.60*** (19.36)	67.20** (21.26)
Ethnic community emphasis squared	H2	-16982.69*** (4315.04)	-2452.01*** (579.83)	-2409.15*** (508.56)
Inter-organizational mobility	H3A	0.05 (0.10)	0.03 (0.03)	0.02 (0.02)
Inter-regional mobility	H3B	-0.009 (0.11)	-0.004 (0.02)	0.03 (0.02)
Controls				
Organizational community emphasis		0.14 (0.13)	-0.007 (0.09)	0.03 (0.06)
Inventor experience		OMITTED	OMITTED	OMITTED
Collaborators		0.04*** (0.005)	0.05*** (0.003)	0.04*** (0.005)
Inventor order		-0.03 (0.06)	-0.15** (0.05)	-0.06 (0.05)
Firm age		-0.00003 (0.004)	-0.004 (0.003)	-0.002 (0.004)
Firm public		0.14 (0.11)	0.09 (0.10)	0.07 (0.11)
Firm knowledge base		-0.00002 (0.00002)	0.00002 (0.00002)	0.000007 (0.00002)
Lagged inventor quantity		-0.009 (0.04)	0.003 (0.009)	-0.006 (0.008)
Wald Chisquared		584.57***	809.76***	624.59***
N		375	316	271

Standard errors in parentheses
* p<0.05, **p<0.01, ***p<0.001

Appendix 1- Summary statistics

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Innovativeness of Indian inventor (quality)	1.00															
2. Innovativeness of Indian inventor (quantity)	0.70	1.00														
3 Geographic emphasis	0.50	0.48	1.00													
4. Technological emphasis	0.33	0.35	0.34	1.00												
5. Ethnic emphasis	0.48	0.73	0.57	0.56	1.00											
6. Inter-org mobility	0.22	0.27	0.12	0.01	0.17	1.00										
7. Inter-reg. mobility	0.15	0.16	-0.02	-0.02	0.07	0.67	1.00									
8. Organizational emphasis	0.09	0.10	0.07	0.13	0.10	0.12	0.05	1.00								
9. Experience	0.06	0.12	0.02	0.01	0.16	0.41	0.35	0.14	1.00							
10. Collaborators	0.63	0.92	0.39	0.33	0.69	0.25	0.18	0.05	0.12	1.00						
11. Inventor order	0.07	0.10	0.05	0.06	0.08	0.07	0.14	-0.006	0.04	0.29	1.00					
12. Firm age	-0.04	0.01	-0.07	-0.05	0.03	-0.13	0.006	-0.23	0.04	0.07	0.11	1.00				
13. Firm public	0.09	0.08	0.10	0.10	0.10	-0.19	-0.06	-0.22	-0.09	0.08	0.10	0.56	1.00			
14. Firm knowledge base	0.02	0.07	-0.02	-0.02	0.09	-0.16	0.05	-0.17	0.07	0.16	0.16	0.62	0.42	1.00		
15. Lagged inventor quality	0.53	0.42	0.44	0.18	0.33	0.31	0.19	0.11	0.13	0.34	0.05	-0.04	0.09	0.02	1.00	
16. Lagged inventor quantity	0.44	0.51	0.35	0.14	0.41	0.34	0.22	0.06	0.19	0.45	0.05	0.01	0.10	0.07	0.76	1.00
Mean	23.86	2.46	0.001	0.008	0.001	1.07	0.86	0.10	4.68	6.72	1.51	23.5	0.63	2373.20	15.17	1.59
Standard Dev.	39.14	3.09	0.006	0.02	0.003	1.95	1.88	0.39	5.46	9.18	0.82	15.82	0.48	3185.96	37.78	3.22

Appendix 2 - Assignment of patents to Indian inventors

We followed Lissoni, Sanitov, & Tarasconi (2006) and Breschi and Lissoni (2009) to develop a unique code to identify inventors based on names, technology class and assignee firms. We use the following inventor, Prathima Agrawal, from our sample to illustrate the process adopted. Tables 5a and 5b show a sample of the outcomes based on the last name and first name search for Prathima Agrawal, respectively. Table 5a shows that patents 5091872, 5093920, and 5257268 belong to Prathima Agrawal. Although the inventor locations (city, state) have changed, all the patents are assigned to AT&T Bell Laboratories. We therefore conclude that these three patents are all assigned to the same inventor, Prathima Agrawal. In addition, patent 5722051 also belong to Prathima Agrawal, but to a different assignee—Lucent Technologies. However, based on information from SDC dataset, we note that Lucent Technologies was created in 1996 as a spin-off of AT&T and it is composed of Bell Laboratories. Therefore, we conclude that all these four patents belong to Prathima Agrawal, while she was working for one employer (i.e., she did not change employer during the period of these patents). Using a similar approach, we find 15 patents belong to Prathima Agrawal by searching on her first name—Prathima. Results are partially illustrated in Table 3b.

Table 5a. Patent out come based on search of last name-Agrawal

	Patent No.	First name	Middle name	Last name	City, ST	Assignee
1	5902539	Amit	Suresh	Agrawal	Merrimack, NH	Continental Pet Technologies, Inc
2	5091872	Prathima		Agrawal	New providence, NJ	AT&T Bell Laboratories
3	5093920	Prathima		Agrawal	Union County, NJ	AT&T Bell Laboratories
4	5257268	Prathima		Agrawal	New providence, NJ	AT&T Bell Laboratories
4	5722051	Prathima		Agrawal	New providence, NJ	Lucent Technologies Inc.
5	5657240	Vishwani	D.	Agrawal	Murray Hill, NJ	NEC USA, Inc

Note: There are total 382 patents based on last name search, within which there are 15 patents by Prathima Agrawal. Results abbreviated for presentation

Table 5b. Patent out come based on search of first name-Prathima

	Patent No.	First name	Middle name	Last name	City, ST	Assignee
1	5091872	Prathima		Agrawal	New providence, NJ	AT&T Bell Laboratories
2	5093920	Prathima		Agrawal	Union County, NJ	AT&T Bell Laboratories
3	5257268	Prathima		Agrawal	New providence, NJ	AT&T Bell Laboratories
4	5722051	Prathima		Agrawal	New providence, NJ	Lucent Technologies Inc.

Note: There are total 15 patents, which match perfectly with the first name search.