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R&D offshoring and the domestic science base in India and China

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Keywords: R&D offshoring/internationalisation, Science base, Emerging economies, India and China

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Abstract:

This paper uses patent and publication data to assess the nature of technological advantages that are attracting R&D offshoring and outsourcing activities to India and China and the possible consequences of such R&D offshoring in increasing domestic innovative capability and building domestic research infrastructure. We find evidence that domestic patenting is concentrated in sectors that are different from sectors of R&D offshoring. Furthermore, whilst the domestic science base (as measured by publications data) in India and China shows strong complementarities in its specialisation profile to that in the US, our data also suggest that the location of international R&D activity in these economies from 1995 may not have strengthened the science base of these economies. Foreign patenting activities in India and China are also marked by a low attachment to the science base.

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R&D offshoring and the domestic science base in India and China

1. Introduction

Multinational affiliates are spreading their R&D activities to newer regions of the world. In a review of trends in internationalisation of R&D activity by UNCTAD (2005) both China and India emerge as the most popular future destinations for multinationals R&D activity. US firms have led these trends towards R&D offshoring in India and China, although the role of Korean and Taiwanese firms in China is also known to be significant. Since 2000, a number of European countries have followed with firms from the UK and Germany leading the offshoring of technology.

These trends have given rise to some policy dilemmas in the area of science and technology. From the point of view of countries in the developed world the issue is whether the internationalisation of R&D in newer regions represents cost saving concerns of R&D intensive companies or if there is a real challenge coming from the technological base of these two newly emerging market economies. There is also anxiety that offshoring might leak innovative knowledge to domestic firms in China and India thus giving rise to future competitors (Samuelson, 2004, Economist, 2007).

In a globally competitive economy the anxieties of one country may often represent an opportunity for another. Thus, R&D off-shoring by OECD countries might offer benefits to India, China and other labour abundant poor countries. These beneficial effects could come about through various channels – by creating demand for educated labour, by technological spillovers from MNEs and learning from quality conscious MNE customers. Although both India and China have seen a great export of their student population, the effects of R&D offshoring on their domestic universities remains ambiguous. Studies on Bangalore where a large amount of R&D offshoring to India has taken place have also mostly failed to find significant linkages between foreign firms and the local economy and the sort of inter-firm networks one would expect in the presence of traditional technology spillovers (Parthasarathy 2004).

Our paper is an empirical attempt to examine the issues surrounding foreign patenting in India and China and the linkage of such offshore R&D activities to the domestic science base, as evidenced by publications data. Section 2 below assesses the literature on R&D

outsourcing to derive some propositions about its impact on the science base. Section 3 describes the nature of the data and the empirical methods used in this paper. Section 4 describes the trends in technological activity and the science base in India and China while Section 5 analyses the characteristics associated with knowledge intensive patents. Section 6 concludes.

2. R&D offshoring and the science base

Traditional wisdom suggests that firms would keep R&D activities strongly localised so as to best utilise the managerial resources that target R&D towards areas of competitive advantage. In a seminal paper Patel and Pavitt (1991) argued that despite the increasing globalisation of business, technological activities of large firms tended to stay in their countries of origin and show a close relationship to country competences. This 'non-globalisation' of technological activities accords with many known features of major innovations that make the management of R&D difficult: the person-embeddedness of multidisciplinary scientific research, the largely tacit nature of technological knowledge, the strong need for coordination in decision making in the face of uncertainty of innovation, all of which made proximity to headquarters important.

Other costs are pointed out in the international business literature. The 'liability of foreignness' – a term coined by Zaheer (1995) to emphasise the difficulties of replicating organisational structures at home in operations abroad--would be more not less in the relocation of R&D activities. The spread of R&D to newer regions could also mean handling the sorts of 'costs of distance and foreignness' traditionally discussed in analyses of international expansion of production. The prominent costs are those involved in different legal frameworks especially with regard to intellectual property and contract enforcement and the psychological distances associated with different languages and work cultures.

The large scale movement of R&D to developing regions of the world like India and China clearly fly in the face of this traditional wisdom about the rising costs of undertaking global R&D, but are indicated in several recent studies. Beausang (2004: p. 2) cites figures from the US Department of Commerce to show that R&D undertaken in US-owned TNC affiliates abroad rose from $7,922 million in 1989 to $18,144 million in 1999. It was not only the volume of international R&D activities of multinationals that had increased, it had also spread to newer regions of the world, such as Developing Asia.

Thus, in the late 1990s the main hosts for US- affiliate R&D expenditures were Europe ($12,217 million in 1999) followed by Asia and the Pacific region ($3,266m in 1999) and Canada ($1681m). The share of Developing Asia (defined as Asia and Pacific but excluding Australia, New Zealand and Japan) rose rapidly from under 1% in 1989 to about 8 % of all R&D undertaken in foreign locations. Much of Developing Asia's affiliate R&D is concentrated in specific sectors in manufacturing, viz. computers, transport equipment and chemicals (in decreasing order of importance).[1] These trends are confirmed in figures reported in UNCTAD (2005) devoted to analysing the internationalisation of R&D.

Another tradition of scholarship has always pointed to the considerable efficiency gains for large firms due to the internationalisation of their R&D activities. Drawing on the OLI framework popularised by John Dunning, these scholars argue that the internationalisation of R&D is the result of a complex interaction between the ownership advantages of MNCs and the location advantages of regions. Cantwell (1995) for example, explicitly predicts that in a global world, MNCs will locate to exploit regions of differential advantage in production and in R&D. Such gains can arise through several channels: because of the lowering of the costs for routine R&D, the rationalisation of human capital intensive activities and the growing ability of MNEs to source new types of skills, networks and the science base in emerging regions. In a similar vein, Kummerle (1997) distinguished between the home base augmenting and home base exploiting investments of MNEs. Whilst the latter activities were traditional asset exploiting FDI activities, the home base augmenting investments were designed to build up the asset base of companies through R&D investments abroad. Using this framework, UNCTAD (2005) argues, as multinationals move from largely 'asset exploiting' to 'asset augmenting' investments drawing on global sources of competitive advantage, the spread of international investments in technology perhaps mirrors a pattern that emerged in international production in the 1970s and 1980s.

Criscuolo and Narula (2007) have provided a fresh perspective on this issue drawing together ideas in the national systems of innovation tradition and using them to understand patterns of internationalisation of R&D. They argue that it is best to understand the international R&D sourcing process as being enmeshed in two National Systems of Innovation- on one hand the MNE is embedded in the home economy and through its internationalisation activities the MNE seeks to embed itself in the host

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[1] Beausang (2004), p. 2 and Table 2.

economy to which it is drawn. However, these investments take place in the context of technological uncertainty- the extent of which differs from sector to sector. Looked at in this way there may be considerable organisational inertia in the R&D offshoring process which may make it difficult to get going, but once this inertia is overcome the MNE gains from the national systems of innovation in both economies. The managerial efficiency of multinationals then drives them to internationalise their technology through 'asset augmenting' investments rather than 'asset exploiting' investments alone.

The empirical literature on the location of R&D investments has identified four main motives in MNEs' offshore R&D decisions. First, MNEs need to be close to their clients for the purposes of product development and modification. Fors and Zejan (1996) and more recently UNCTAD (2005) have suggested that MNEs' offshore R&D is often located close to their large overseas production facilities. Firms are keen to reduce product development times by locating R&D in time zones that allow a 24/7 use. India definitely falls in this category of location sites for US firms. Second, MNEs locate R&D abroad in order to access new foreign technologies for the development of new products and processes. For years the US has drawn this kind of investment from East Asian firms and European firms (Dambrine 1997, Volker and Stead 1999). Fors and Zejan (1996) also argue that R&D facilities of MNEs will tend to be located in countries with a technological specialisation similar to their own and that this allows them to take advantage of foreign centres of excellence and knowledge spillovers. Niosi (1999) has shown that locating R&D in foreign countries can be a means of broadening the scope of the parent's technological portfolio.

The third motivation for locating R&D investments overseas is to take advantage of large local markets. This factor emerges as important in Kumar (2001) and is also consistent with the work of Gao (2000) who analysed data for foreign affiliates' R&D investments in 16 OECD countries and found host market size as one of the most significant factors attracting affiliate R&D expenditure.

The availability of R&D labour has emerged as an important fourth factor driving R&D investments abroad particularly in the context of R&D investments to developing economies like China and India. The empirical analysis in Kumar (2001) shows this as an important factor explaining the location choice of R&D subsidiaries by Japanese and US MNEs. Hicks and Hegde (2005) analyse the factors that influence both the probability and extent of US overseas R&D activity. Their results suggest that while variables like market access and technological strength predict US R&D overseas as much of the empirical literature has suggested, the strength of patenting from particular locations is strongly dependent on the nation's Science and Engineering (S&E) capability. This effect is particularly significant in the relatively new electronics and computers industry, as well as in the traditional sectors of transport, metals, and industrial machinery. They call this the 'S&E capability premium' of nations.

Hypothesis 1: The science base and the availability of scientific labour are an important factor attracting R&D offshoring into India and China and this will be reflected in the presence of more knowledge-intensive MNEs in India and China.

The value of international R&D performed in different regions is only just coming under scrutiny. Criscuolo et al (2005) attempt to infer the motivation of R&D using patent citations of US MNEs based in the EU and European MNEs based in the US. Their results indicate that both EU affiliates in the US and US affiliates in the EU rely extensively on home region knowledge sources, although they appear to exploit the host country knowledge base as well. An important and exciting area of empirical work that has opened up concerns the nature and organisation of R&D tasks in the newly developing regions of China and India. Zedtwitz and Gassman (2002) develop a taxonomy of archetypical organisational forms adopted by foreign affiliate R&D depending upon whether the R&D mandate is market-seeking or technology seeking. Based upon an analysis of 1021 R&D units, each distinguished by its main orientation towards either basic research or development work, Zedtwitz and Gassman (2002) show that basic research is concentrated in only five regions worldwide, while developmental research is more globally dispersed. Differences in R&D internationalization drivers thus lead to a separation of individual R&D units by geography – however the needs of coordination create a tension that the different organisational forms try to resolve. In another study, Zhao (2006) has argued that MNEs can profitably locate R&D in developing countries with weak contractual and IPR regimes because they are primarily concerned with knowledge flows within the firm. IPR costs and contractual hurdles are more likely to be costs governing knowledge flows from one firm to another. Based on data for the semiconductor sector, she shows that Chinese patents of US MNEs more often cite own-firm patents than other-firm patents—a pattern we would expect if task partitioning were to situate developmental work in Chinese R&D labs intended for further use within the firm. We are not aware of similar studies for India, possibly because the overall inward investment activity in India is small and R&D investment has hitherto been mostly in the IT sector. The hypothesis suggested by these studies is that the value of patenting activity measured in terms of standard indicators like knowledge intensity or forward citations by other patents is likely to be low.

Hypothesis 2: The knowledge intensity of R&D offshoring by MNE firms in India and China is likely to be low, relative to their R&D from other regions.

Very little is known about the impact of such R&D activity by MNEs on the science base of the Indian and Chinese economies. Based on their study of software outsourcing to India, Arora and Athreye (2002) argued that the growing demands for engineering labour had resulted in increasing wages but also a privatisation of the supply of training. Yet this co-exists with a situation where basic research is losing its senior staff to lucrative multinational jobs and their junior staff is no longer interested in academic/research jobs. The Chairman of the Indian Institute of Space Technology, Mr G. Madhavan Nair has said publicly that the gap between the wages to a career in industry and wages to a career in science establishments like ISRO should be narrowed in the interest of the country's future human resources. "There has been no investment in HR. After five years, the quality of students will be very poor. This is the time for all of us to ensure that we have good teachers and students in the future," Mr Nair said. He also felt private industry should also re-invest in education as a pay-back gesture and help replenish the scientific pool for the future.[2]

If the concerns expressed by Indian space agency chief scientist have general merit, it raises a policy dilemma for developing nations that has received scant attention. In a situation of global scarcity of engineering and scientific talent the human capital resources of developing countries (often built over years of subsidy by domestic taxpayers), are being raided by lucrative salary offers from Western firms. This has often been seen as a boon and a just reward for poor countries that have made the right investments in human capital. Yet, the long-term consequence of such a raid to the economy as a whole may be the steady erosion of domestic science institutions in such countries unless a plan is put into place where corporate profits can be diverted to the replenishment of their human capital.

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[2] "ISRO chief calls for 'level playing field' to stem exits", *Business Line*,14 September 2007.

Hypothesis 3: R&D offshoring is eroding the science base of Indian and Chinese economies in the short-term.

3. **Data and Methods**

3.1: Data and Variables

The aim of our empirical analysis is to look for the science and technology (S&T) pull factors behind R&D offshoring to India and China and to examine if R&D offshoring has been accompanied by a strengthening of the S&T base in India and China. Our analysis utilises two publicly available databases on technological outputs coming out of China and India, viz. their USPTO patents and scientific publications.

Patent data [3] have been extracted from the US Patent Office website www.uspto.gov, while data on scientific publications have been collated from Thomson-ISI Science Citation Index. The latter data were compiled by Science Metrix Inc from Science Citation Index (SCI) data prepared by L'Observatoire des Sciences at des Technologies (OST). Patent data give various types of relevant information on patents. In common with many papers based on patent data, we look at first inventors of patents, in this case where the first named inventor is Chinese or Indian (see for example Trajtenberg 2001). In addition however we also use information on the nationality of any inventor, where any of the inventors in the team is Chinese or Indian.

Appendix Table 1 shows the difference the two classifications make to the overall patent count. We are able to count about 25% more patents for India and 30% more patents for China. By also considering co-patenting activity when the Indian or Chinese inventor is not the first inventor we are able to obtain valuable information on global linkages in innovative activity exploited by offshoring firms.

Data on scientific publications look at the relative specialization in terms of scientific fields within China, India and the US. To provide an indicator of the quality of the domestic science base we also measure the relative impact factor of publication. The term relative is used to indicate a comparison with world averages in both cases.

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[3] The period covered by the patent data are from 1 Jan 1976 to 1 June 2006

Using both these datasets (on patents and publications) we constructed the following specific variables.

(i) **Knowledge intensity of the patent**: Patent data often cite the non-patent citations to scientific papers and articles. The number of 'science references' per patent has now become a standard way of quantifying the impact of basic science on technology (Narin, F., Hicks et al., 2001, Leydesdorff, 2004, Tamada et al., 2006). Nomaler and Verspagen (2007) argue that this is a noisy measure of the basic science/ knowledge intensity of patents because many citations are put in by examiners rather than inventors. Furthermore, not all non-patent citations refer to scientific journals alone. Despite these known limitations of this measure, we use it as the dependent variable in our multivariate analysis and a measure of how much patenting from India and China draws upon the science base.

(ii) **Foreign Ownership of the patent**: We classified whether the assignee was a domestic company, university/research lab or whether the assignee was a foreign company, university or research institute. We elaborate a finer classification in some of the descriptive tables. The ownership variable is a dummy variable which takes value 1 if the ownership is foreign and 0 if the ownership is domestic.

(iii) **Technological class of the patent:** The US Patent Office has developed an elaborate classification system of over 400 main patent classes, 36 sub-categories, but we use the six main categories of patents as developed by Hall et al (2001) viz. Computers and Communications, Electrical and Electronics, Drugs and Medical, Chemical, Mechanical, and Others. We added new technological fields to the existing 6 broad categories.

(iv) **Nationality of the First inventor:** As mentioned before the convention in patent data analysis is to use the nationality of the first inventor as indicating the national origin of patents. Following this logic we create a dummy variable which takes on value 1 if the first inventor is Indian or Chinese and zero if the first inventor belongs to any other nationality. The patents coded zero also give valuable information on domestic and MNE patenting from other locations involving Indian inventors.

(v) **Period:** Dummy variables were created for each one of three periods viz. 1973-85, 1986-95 and 1996-2006.

(vi) **Scientific field of the patent**: the scientific knowledge that a patent draws upon. Nine dummy variables were constructed to signify the scientific disciplines of Biology, Biomedical research, Chemistry, Clinical medicine, Earth and Space, Engineering and Technology, Mathematics, Physics and a residual category of Other fields which included Psychology and Social Sciences. This variable was constructed by matching each of the non-patent citations to the broad scientific field of that publication as indicated by the publications data. These matched entries allowed us to construct dummy variables for scientific fields cited in the patents.[4]

3.2 Empirical Methods

Our regression model looks at the relationship between the number of non-patent citations (as a proxy for dependence on the science base) as a function of certain characteristics of the patent: whether it is foreign-owned or domestic, whether its first inventor is Indian/Chinese or not, which period it comes from, and which scientific discipline and technological field it relates to.

The choice of multivariate regression model is dictated by the nature of the dependent variable- non-patent citations are a count variable which is also skewed. Nomaler and Verspagen (2007) note that the overall average of non-patent citations reported in other studies tends to be rather low at about 1 citation per patent and over 60% of patents register no non-patent citations at all. This dictates choice of either the Poisson model or the Negative binomial model as the underlying distribution which relates the dependent variables to the characteristics variables.

The Poisson model assumes that the number of citations to a patent is a random variable that is approximated via a Poisson process, in which the mean is equal to the dispersion of the data. This implies that the probability of obtaining q non-patent citation counts of patents in a particular year is given by

$$\Pr(y = q) = \lambda^{q} \frac{e^{-\lambda}}{q!} \text{.........(} \quad 1)$$

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[4] Thus, matching the 25,259 non -patent citations from Chinese and Indian patents to the journal database (Thompson SCI) we found that only 12,775 non-patent citations could be matched to scientific fields. Thus, in our sample, 12,484 citations could not be matched. Analysing a sample of 100 citations from these unmatched citations and tagging each of them with an explanation to why they didn't match we found that half of them were journals that are not indexed in the SCI and the other half are not citations to scientific journals but to web-based information such as electronic journals, databases and quality standards. There were no discernible biases towards any one of these categories.

Here, λ is the expected value (and the variance) of the random variable q. Poisson regressions estimate this parameter in log-linear models of the form

$$\log(\lambda) = \beta' x ....(2)$$

using the method of maximum likelihood.

An alternative is to use the negative binomial model, which is amore generalised process and takes the form

$$\Pr(y|x) = \frac{\Gamma(y+\alpha^{-1})}{y!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\lambda}\right)^{\alpha^{-1}}\left(\frac{\lambda}{\alpha^{-1}+\lambda}\right)^{y} \qquad (3)$$

In the context of count regression models the negative binomial distribution can be thought of as a Poisson distribution with unobserved heterogeneity which, in turn, can be conceptualized as a mixture of two probability distributions, poisson and gamma. As can be seen from equation (3) above, there is an extra parameter of estimation (α) when compared to equation (1). If α = 0, the negative binomial model reduces to the Poisson model (Cameron and Trivedi, 1998).

Deciding which model is most appropriate is not straightforward. If the underlying true distribution is not negative binomial, estimating such models on the data produce inconsistent coefficient estimates (Hall and Ziedonis, 2001). However, Poisson regressions have the appealing property that whether or not the distributional assumptions are met, the estimates of β produced will be consistent and asymptotically normal (Wooldridge, 2000: Chap. 17). Thus, in Section 5 of the paper, we report both the Poisson and Negative binomial estimations.

4. New regions of technological advantage? A descriptive analysis of the data

4.1: Trends in patenting

From an initial patent count, the technological competences of some parts of China and India appear to be growing fast. Thus, the stock of (first inventor) Indian patents with the US Patent Office was 864 between 1996-2000 which increased to 1127 patents for the period between 2001-2003; for China there were 795 (first inventor Chinese) patents registered with the US Patent Office between 1996 and end-2000 increasing to 1133 patents for the period 2001-2003. As Appendix 1 shows these figures are even higher when we include the second, third, fourth and fifth inventors that are Chinese or Indian.

The figures from the USPTO data mirror trends noted in studies which measure the growth of domestic patenting in China and India. Hu and Jefferson (2006) show that there has been an explosion in China's domestic patenting since China amended its patent law in 1992 and again in 2000, and estimate the annual rates of growth of domestic patenting to be around 23 per cent. Similarly, Ramanna (2002: pg.3) notes that patent applications in the Indian patent Office more than doubled following the patent policy reforms in 1994-95, thus significantly reversing the declining trend in average patent applications from 5100 in 1970-71 to 3,500 applications between 1985-1992.

To put the above data on the rate of patenting in an international perspective, we compare the USPTO statistics on India and China from 1976-2005 with three reference groups shown in the three panels of Figure 1. The first panel includes data on Brazil and Russia, these being the two other large, middle-income, emerging markets. The second panel consists of countries that have been successful in the second wave of technological catch-up – Taiwan, South Korea, Hong Kong and Singapore. The third group is a comparison with the G7 countries. We follow Trajtenberg (2001) and report patenting data by application year rather than issue year.

Figures 1a-c show that patenting in China and India has increased and both have overtaken Brazil and Russia in levels. This supports findings elsewhere: Athreye and Cantwell (2006) show that between 1993 and 2001 both India and China were amongst the top gainers in the rankings of country shares of patenting in the US and also in the share of worldwide licensing revenues. However the remaining two panels indicate that despite a rising trend patenting in India and China is still a long way behind G7 countries and East Asian NICs in the level of patenting activity.
[Figure 1a-c here: Patents granted by application year, three panels]

The success rate of patent applications is reported in Table 1.[5] Success rates of patenting increased for China from 44.9 for the period 1986-95 to 65.5 for the period 1996-2001, and for India from 51.7 in the earlier period to 72.8 in the later period.
[Table 1 here]

Table 2 shows the number of scientific publications by selected countries, NICs, G7 and world by three year period between 1990 and 2004. Between 1999-2001 and 2002-2004 publications of scientific papers from China increased by 65% and from India by 21% compared with a 5% fall in the number of papers published in Russia and an increase of 34% in Brazil. In the same period the G7 scientific publications increased by just over 2% whereas the NICs' publications increased by 30%, mostly from Korea and Taiwan. Measured by the stock of scientific papers, the publication data suggest that scientific capability in China and India rank below Russia but above South Korea, Brazil and Taiwan. This picture would of course change if we considered per capita publications or publications per 1000 scientists.
[Table 2 here]

Thus, the data on patenting and publications taken together strongly suggest a growth of the science base and technological capability in China and India. However, they also suggest that the per capita additions to the stock of patents and publications are probably very low when compared to more advanced economies, reflecting the poorer access to science and technology in large parts of their sizeable populations.

Table 3 below divides Indian and Chinese patents into domestic and foreign patents looking at the assignees of our databases of patents where the first inventors are Indian or Chinese. We have distinguished between three periods: 1976-85, 1986-95 and 1996-2006. The proportion of domestically owned patents of all first-inventor patents steadily increases in India from 23% (with 57% foreign owned) to 40% (44% foreign owned) to 61% for the most recent period (33% foreign owned). This contrasts with China where the proportion of domestically owned patents remains at 33% in the early period, 45% in the middle period and 33% in the most recent period whilst the proportion of foreign-owned patents increases markedly from 27% to 19% to 47% in the most recent period.[6]

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[5] The rate of success of patent applications is the number of patents granted (by application year) divided by the total number of patents applied for in the US by Chinese or Indian first inventors.
[6] The proportion of unclassified assignee firms in China falls from 40% to 36% to 21%.

[Table 3 here]

The rise of patenting by domestic firms in India is in contrast to the growth of patenting by foreign firms in China. Closer inspection of the Indian data however reveals that the assignee with the largest number of patents (682 patents) is the Centre for Scientific and Industrial research - a public sector research laboratory- followed by three US firms (Texas Instruments Incorporated with 151 patents, General Electric Company with 133 patents and IBM with130 patents). Domestic pharmaceutical firms are the next important category of assignees but their combined holdings do not add up to the patent holdings of even one of the US firms from India. Thus, if we were to take out the patents owned by CSIR as a special category, then foreign firms would dominate patenting activity in India as well.

The dominance of foreign firms is consistent with trends in R&D offshoring noted earlier but do cast doubt on the extent to which the growing patent stock of India and China at the USPTO actually represent technological capability amongst domestic firms and of the region as a whole. The importance of the public sector patents in both countries is noteworthy. In India, we have already remarked on the dominance of the CSIR. In China, the 71% state-owned Chinese Petroleum and Chemical Corporation was the second largest assignee with 103 patents and Tsinghua University with 20 patents was also among the top ten assignees. Patenting by the public sector can in principle achieve a rapid diffusion of scientific knowledge. In practice, this is likely to depend upon the uptake of such research by domestic companies and our data do not give us information in this regard.

4.2 The technological composition of patents

Table 4 shows the broad technological fields of patenting by domestic and foreign firms. Over 80% of domestic patents in India are chemicals and drug patents, while half of all foreign firm held patents from India are in Computing and electrical sectors. The clear separation of areas of patenting by foreign and domestic firms suggests they are not in competition with each other for the labour pool or scientific expertise in the economy. Chinese domestic patents are more evenly distributed in all groups except computers, while more than a third of foreign patents are concentrated in the electrical sector. An implication of this finding of different distribution of patents is that foreign firms and domestic firms may compete more often for the same type of labour talent/ science base in China.

[Table 4 here]

4.3 The knowledge intensity of patents

Tabulating the non-patent citations of Indian and Chinese patents helps us to understand to what extent domestic and foreign patents are likely to draw upon the science base. The higher the count of non-patent citations, the more knowledge intensive and science based a patent is likely to be. Table 5 below reports the average number of non-patent references by period and type of owner.

[Table 5 here]

Indian patents showed a higher number of average non-patent citations when compared to Chinese patents and in both countries the average numbers of scientific citations have risen over time. However, there is a distinct difference between the scientific intensity of foreign patents and domestic patents with domestic patents in both countries showing a larger number of average non-patent citations when compared to foreign firms, especially in the last period (1996-2003). This picture is however reversed when we look at non-patent citations of foreign patents where second to fifth inventor of the patenting team is Chinese or Indian. In the table these are labelled 'any inventor' and they exclude the first inventor patents. Here we find that the non-patent citation intensity of foreign owners is higher than the non-patent intensity they exhibit in the case of first inventor Chinese or Indian patents. However, it is well known that non-patent citations do vary systematically by technological sector.

4.4 Characteristics of the Science base: analysis of the publications data

In order to draw a picture of the national science base in China and India, we draw upon two measurable aspects of publications. The first is Relative Specialisation. Relative specialisation is the ratio of publications of a particular subject field of a country's total publications, divided by the same ratio for the world. If the index is greater than one this implies that the country is relatively specialised in the particular field of science. This may be thought of as a measure of the relative effort of the country or the relative intensity of research in a given field by that country relative to the effort in other parts of the world. A higher proportion of publications in chemistry from India relative to its overall share of world scientific publications would be reflected in a specialisation index with value greater than 1. The larger the value of the specialisation index the more is the relative effort devoted to the sub-disciplines.

The second index we consider when evaluating the science base of an economy is the average impact factor (ARIF) of publications emanating from each sub-field. The impact factor measures the quality or importance of the papers published in a given field. It is calculated using the number of citations received by journals in which papers are published. Values of the average impact factor that are greater than 1 reflect papers of good quality because the journals in which they are placed receive more citations than the world baseline figure. Conversely if a paper is published in journals which receive below a world baseline figure for citations, the impact factor drops to below 1. Impact factors of below 1 show a tendency to publish in local journals which are less visible internationally or which tend to have papers of lower quality. This could be caused by various factors such as lack of adequate research facilities, weaknesses in the education system, scientific and technological outflows to other countries (Science Metrix 2003).

Figure 2 shows the positional analysis of countries using specialization index, impact factor and number of papers over the period, 1990-2004. The horizontal axis measures the log of the specialisation index and the data are transformed so that the vertical axis represents the World level. Similarly the vertical axis measures the log of the ARIF and the data are scaled so that horizontal axis itself represents the world levels in terms of impact. The number of papers is measured by the size of circles. Figure 2 shows that Brazilian, Chinese, Indian and Russian publications mainly lie below the horizontal axis indicating their poor impact quality, though Mathematics in Brazil shows world quality publications. In contrast, all the US publications are at world quality. However, the specialisation indices are more interesting. US scientific fields on the left of the vertical axis (which show scientific fields where the US is less specialised) are exactly matched by Indian and Chinese specialisations on the right of the axis. However the impact factors corresponding to the specialisation indices are low reflecting the poorer quality of the

scientific infrastructure. Thus the publications data reveal a remarkable complementarity between the science base in the US and the science base in China and India.
[Figure 2 here]

Looking at the averages reported in Table 6, we see that the figures for the US show a relatively low specialisation in Physics, Chemistry, Engineering and Mathematics (all these fields have average specialisation indices less than 1). Interestingly, however, these are precisely the areas where China shows relative specialisation (average specialisation indices closer to 2). India shows relative specialisation in Chemistry, Physics, Engineering, Earth and Space. Thus, there are strong complementarities between the existing science base in India and China when compared to the US science base. Their scientific effort is higher in precisely those areas where the US scientific effort is lower than the world average.

Another distinctive feature of the Indian and Chinese science bases highlighted in Table 6, especially when compared to other large low-wage economies like Brazil and Russia, is the relatively higher specialisation in Engineering disciplines. This is of course also reflected in their patenting profiles -- a strong engineering capacity had been an important predictive factor in the industrial and technological development in the US, Germany, South Korea and Taiwan.
[Table 6 here]

Table 7 below also reports the average of relative impact factors across countries and scientific fields. The US shows high quality in all fields, while India China and Russia show ARIFs less than 1 in every sector and overall. However, Brazil shows publications of world quality in Physics and Mathematics.
[Table 7 here]

5. Characteristics of knowledge-intensive patents

5.1 Empirical results

Table 8a & 8b below report the results of the Negative Binomial and Poisson regressions respectively. These regressions are intended to shed light on the characteristics of the more knowledge intensive (science-based) patents and the results of the two models do not differ substantially.

[Table 8a & 8b here]

Looking first at Chinese patents we find that foreign ownership is associated with a positive impact on the knowledge intensity of patents when controlling for the effect of technological sectors of patenting. However, patents with first inventors that are Indian or Chinese are less science intensive. Thus, both foreign and domestic firms draw more science-based patents from teams of scientists where the first inventor is not Indian or Chinese, possibly residing in their home countries or other overseas locations. The knowledge intensity of Chinese and Indian patents has increased overtime and it can also be seen that pharmaceuticals and chemicals are the more science intensive sectors. The next set of results includes the scientific fields of the non-patent citations. Here we find that patents that cite papers from the sub-fields of engineering and technology, health sciences, maths and physics are less likely to be knowledge intensive.

The estimations on Indian patents broadly confirm these results. Foreign firms are more likely to draw knowledge intensive patents when controlling for other factors such as technology class. The knowledge intensity of Indian patents has been increasing overtime and drugs and chemicals remain the most knowledge intensive sectors. Some differences from the Chinese results emerge when we consider the scientific fields of the non-patent citations. Thus, we find that relative to patents with unassigned scientific field of citations, patents that draw on Chemistry, Mathematics and Physics are not knowledge intensive patents. Patents with Engineering and Technology citations are likely to be associated with significantly lower knowledge intensity.

5.2 Implications of the empirical analysis

The results of the multivariate regression have interesting implications for the three hypotheses we outlined earlier in the paper. The association of foreign rather than domestic firms with more knowledge intensive patents points to the importance of the science base for drawing R&D offshoring from MNEs to China and India. This reinforces the message of Figure 2 which showed the complementarities in the science specialisation in the US on the one hand and India and China on the other, thus supporting our first hypothesis.

However, the relatively low knowledge intensity of patents, especially in teams where the first inventor resided in India or China, also points to the relatively lower knowledge intensity of patents drawn locally. Another way to think about this result is that more knowledge intensive patents come from teams where the first inventor is resident in other locations for both domestic and foreign firms in the sample. This finding thus supports the conjecture of our second hypothesis.

The inclusion of scientific fields of the citations gives us some further insights. Despite the strong complementarities in specialisation between the US science base and that of China and India, the scientific fields of complementarities viz. Engineering, Physics and Mathematics were not associated with more knowledge intensive patents. We conjecture that this is because labour skills are more important than the universities of the regions in drawing R&D offhsoring - a point also made by recent work based on survey data by Lewin et al (2007). However, it is also possible that companies may be deterred by the low IPR protection and therefore they locate only low knowledge-intensity work in these regions as argued by Zhao (2006).

While MNE offshoring can be drawn to scientific strengths in complementary areas, it is equally likely that the presence of US R&D centres draws scientific investments into the disciplines that are in demand and thus strengthen the science base of domestic economies. We look at specialisation indices before and after 1995 and exploit the fact that offshoring of R&D as a trend gained strength in the US after 1995, and from Europe after 2000 in order to assess the impact of offshoring on the strength of the science base in India and China. If offshore R&D had been drawn by areas of specialisation then we would expect to see complementarities between the science bases even in the period 1990-1994. Further if such complementarities between the science bases strengthened after the advent of offshore R&D firms then we would expect specialisation in Maths, Physics, Chemistry and Engineering to become visible and increase in the post-1995 period.

Table 6 above had reported the specialisation indices for the three sub-periods 1990-94, 1995-1999 and 2000-2004. First we notice that both China and India show specialisation in Chemistry, Engineering and Physics even in 1990, before offshoring of R&D became a big factor in the economy. China also showed a complementary specialisation in Maths. Thus, it is reasonable to infer that offshore R&D from the US in particular was probably drawn to complementary strengths in the scientific base of China and India. However, after 1995, the specialisation drops somewhat in all fields except Chemistry suggesting that the science base is being weakened rather than strengthened after the wave of R&D offshoring.

This finding certainly corresponds to other evidence about skill shortages in India (Ghosh and Mukherjee,2005) and also anecdotal evidence on the negative externality of software outsourcing and its draw on engineering talent on domestic scientific establishments in the public sector and the manufacturing sector in India (Arora and Athreye 2002). These negative externalities may be weaker in China than India, in that there is greater flexibility in the Chinese university environment for scientists to set up their own businesses whilst retaining university positions, whilst the university underpins scientists' reputations and contacts when there are difficulties arising in managing technologies, recruiting talent and other such issues.

Interestingly, the picture is quite different for Brazil and Russia, where specialisation in engineering, physics and mathematics increases after 1995 suggesting that recent trends in offshoring might have acted as a signal for increasing effort in scientific disciplines favourable for US R&D offshoring We also looked at the ARIFs over distinct time intervals but found they did not change very much. We should expect this as the quality of scientific output takes a longer time to improve while the effort put into publications can increase more quickly in response to different market trends.

6. Conclusions

Technological capacity is growing in China and India, whether measured by patenting activity or scientific publications data. This trend is mirrored in the publications data from the two countries which also show a dramatic increase. The dominance of foreign firms in patenting from these countries however undermines claims to a strong technologically competitive domestic sector in both countries. In view of these trends, this paper aimed to look at the relation between R&D offshoring and the domestic science and technology base in India and China.

A descriptive analysis of the publications data finds that relative specialisation of scientific publications in India and China mirror scientific areas where the US shows a relative lack of specialisation. Using the knowledge intensity of patents as an indicator of the likely draw on the science base, the paper has also shown that the outsourcing of R&D by multinational firms to India and China is associated with a greater draw upon the science base. The knowledge intensity of locally drawn patents is however low relative to similar patents from other regions. We also find that the areas of science that draw in offshore R&D by MNEs are not the ones associated with more knowledge intensive patents. Further, preliminary results also suggest that post-offshoring, the original strengths of the science base that first drew R&D offshoring to the two economies has weakened.

Taken together the implication from these results is that R&D offshoring cannot be relied upon as the only mechanism to create virtuous cycles of educational investment, R&D and growth. While previous investments in tertiary education have proved instrumental in drawing in R&D offshoring, Governments in India and China will have to do more to replenish the science base and maintain their indigenous technological strengths. Given the beneficiaries of such investment have been foreign MNES there is a case for devising new policy instruments that can induce co-investment between foreign MNEs and national governments of India and China for expansion of capacity in tertiary scientific education.

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Table 1: Success rates (patent applications/patents granted) by application year, in percentages

	1976-1985	1986-1995	1996-2002
China	18.5	44.9	62.1
India	45.0	51.7	68.1
Brazil	39.3	46.8	55.1
Russia	66.4	58.9	60.6
Hong Kong	48.2	53.0	51.6
Singapore	51.6	60.7	68.0
South Korea	43.5	64.7	68.9
Taiwan	26.3	43.2	57.7
Israel	53.2	54.9	53.9
G7 average	61.9	57.4	64.0

Table 2: Number of scientific papers by selected countries, by three-year period, 1990-2004

Country	1990-1992	1993-1995	1996-1998	1999-2001	2002-2004	TOTAL
WORLD	1,581,297	1,772,971	1,938,963	2,057,662	2,172,355	9,523,248
G7	1,172,481	1,328,113	1,428,985	1,488,040	1,521,828	6,939,447
NICS	18,904	33,808	56,962	82,173	106,764	298,611
US	635,999	710,724	723,847	749,964	779,503	3,600,037
Japan	134,263	158,027	185,856	202,400	211,491	892,037
UK	137,308	156,995	176,695	188,099	187,496	846,593
Germany	118,468	136,949	170,872	183,235	186,716	796,240
France	87,215	107,073	123,275	129,745	129,199	576,507
Canada	76,745	86,459	87,837	90,625	95,617	437,283
Italy	51,725	65,970	82,319	90,720	99,955	390,689
Russia	25,203	68,894	66,535	64,459	61,033	286,124
China	20,164	25,358	35,858	55,233	91,393	228,006
India	30,068	31,394	32,445	35,755	43,124	172,786
Brazil	9,894	13,179	19,910	28,296	37,909	109,188
South Korea	5,338	11,356	22,955	36,287	50,079	126,015
Taiwan	8,785	14,736	20,659	25,198	30,912	100,290
Hong-Kong	2,823	4,460	8,831	13,008	15,720	44,842
Singapore	2,044	3,446	4,915	8,417	11,323	30,145

Source: Data compiled by Science-Metrix from Thomson-Scientific data prepared by OST

Table 3: Foreign and Domestic ownership of US Patents in China and India

Issue years	Chinese first inventor patents	India first inventor patents
Foreign all periods	**1755**	**1097**
o/w 1976-85	6	92
1986-95	230	149
1996-2006	1519	856
Domestic all periods	**950**	**1425**
o/w 1976-85	2	28
1986-95	199	74
1996-2006	749	1323
Total all periods	**2705**	**2522**

Table 4: Distribution of patents (1976-05) by technological fields for domestic and foreign patent assignees

CHINA	**Domestic**	**% of total**	**Foreign**	**% of total**
Chemicals	278	29.3	174	9.9
Computers	87	9.2	260	14.8
Drugs	135	14.2	164	9.3
Electrical	173	18.2	634	36.1
Mechanical	150	15.8	215	12.3
Other	127	13.4	308	17.6
Total	**950**		**1755**	
INDIA				
Chemicals	717	51.4	196	17.9
Computers	51	3.7	374	34.2
Drugs	450	32.2	203	18.6
Electrical	64	4.6	180	16.5
Mechanical	61	4.4	63	5.8
Other	53	3.8	77	7.0
Total	**1396**		**1093**	

Table 5: Average number of non-patent citations of Indian and Chinese patents at USPTO

First inventor patents	Chinese patents		Indian patents	
Period	Domestic firms	Foreign-owned	Domestic firms	Foreign-owned
1973-85	0.8	1.18	0.71	0.89
1986-95	1.62	1.65	2.73	2.93
1996-2006	2.07	1.52	4.27	2.99
Overall average	1.70		3.44	
Any inventor patents	Chinese patents		Indian patents	
	Domestic firms	Foreign-owned	Domestic firms	Foreign-owned
1973-85	-	4.78	-	1.44
1986-95	0	6.53	-	6.411
1996-2006	4.21	5.51	2	7.89
Overall average	5.6		7.11	

Table 6: Specialization Index* by field and by selected countries, by five-year period, 1990-2004

Field	Year	US	Russia	China	India	Brazil
Biology	1990-1994	1.12	0.40	0.50	1.06	1.08
	1995-1999	1.09	0.58	0.58	0.95	1.21
	2000-2004	1.11	0.47	0.59	0.87	1.21
	TOTAL	1.11	0.49	0.57	0.96	1.18
Biomedical Research	1990-1994	1.08	0.94	0.31	0.77	1.09
	1995-1999	1.18	0.87	0.43	0.86	0.93
	2000-2004	1.22	0.66	0.57	0.87	0.89
	TOTAL	1.16	0.81	0.48	0.84	0.92
Chemistry	1990-1994	0.80	1.88	1.42	1.91	0.66
	1995-1999	0.80	1.75	1.84	1.97	0.73
	2000-2004	0.78	1.83	2.09	2.00	0.86
	TOTAL	0.79	1.81	1.89	1.96	0.78
Clinical Medicine	1990-1994	1.10	0.26	0.39	0.41	0.81
	1995-1999	1.09	0.16	0.31	0.40	0.90
	2000-2004	1.12	0.15	0.30	0.45	0.98
	TOTAL	1.10	0.18	0.32	0.42	0.93
Earth & Space	1990-1994	1.09	1.42	1.04	1.26	1.46
	1995-1999	1.13	1.28	1.01	1.09	1.06
	2000-2004	1.10	1.63	1.01	1.05	0.86
	TOTAL	1.10	1.45	1.03	1.12	1.03
Engineering & Technology	1990-1994	0.95	0.77	2.09	1.70	0.71
	1995-1999	0.86	1.04	2.03	1.66	0.81
	2000-2004	0.76	1.03	1.88	1.51	0.85
	TOTAL	0.85	0.98	2.02	1.61	0.84
Mathematics	1990-1994	1.08	0.72	2.60	0.76	1.50
	1995-1999	0.98	1.05	2.22	0.76	1.25
	2000-2004	0.88	1.57	1.86	0.69	1.09
	TOTAL	0.97	1.19	2.14	0.73	1.23
Physics	1990-1994	0.76	2.47	2.55	1.43	1.62
	1995-1999	0.70	2.92	2.35	1.58	1.58
	2000-2004	0.69	3.01	1.96	1.52	1.32
	TOTAL	0.72	2.83	2.13	1.51	1.44

Source: Data compiled by Science-Metrix from Thomson-Scientific data prepared by OST. *Baseline: World = 1.00

Table 7: Average of Relative Impact Factors (ARIF*) by field and by selected countries, by five-year period, 1990-2004

Field		US	Russia	China	India	Brazil
Biology	1990-1994	1.11	0.39	0.90	0.80	0.85
	1995-1999	1.11	0.37	0.73	0.75	0.85
	2000-2004	1.08	0.49	0.79	0.75	0.86
	TOTAL	1.10	0.41	0.79	0.77	0.85
Biomedical Research	1990-1994	1.24	0.28	0.77	0.58	0.57
	1995-1999	1.23	0.31	0.54	0.56	0.62
	2000-2004	1.18	0.55	0.60	0.55	0.68
	TOTAL	1.22	0.36	0.60	0.56	0.64
Chemistry	1990-1994	1.46	0.30	0.78	0.67	0.93
	1995-1999	1.37	0.38	0.74	0.70	0.88
	2000-2004	1.31	0.46	0.74	0.73	0.81
	TOTAL	1.38	0.38	0.74	0.71	0.85
Clinical Medicine	1990-1994	1.26	0.20	0.63	0.59	0.83
	1995-1999	1.18	0.58	0.67	0.63	0.96
	2000-2004	1.16	0.65	0.79	0.68	0.96
	TOTAL	1.19	0.48	0.73	0.64	0.94
Earth & Space	1990-1994	1.23	0.44	0.81	0.71	0.84
	1995-1999	1.17	0.61	0.78	0.80	0.94
	2000-2004	1.15	0.64	0.89	0.82	0.94
	TOTAL	1.18	0.59	0.85	0.78	0.91
Engineering & Technology	1990-1994	1.12	0.54	1.00	0.92	0.97
	1995-1999	1.11	0.69	0.94	0.88	0.96
	2000-2004	1.14	0.72	0.94	0.91	0.92
	TOTAL	1.13	0.68	0.95	0.90	0.94
Mathematics	1990-1994	1.09	0.65	0.78	0.90	1.04
	1995-1999	1.11	0.71	0.87	0.93	1.00
	2000-2004	1.13	0.70	0.90	0.88	1.01
	TOTAL	1.11	0.70	0.87	0.90	1.01
Physics	1990-1994	1.29	0.55	0.80	0.87	0.99
	1995-1999	1.26	0.66	0.82	0.91	1.02
	2000-2004	1.26	0.74	0.84	0.90	0.98
	TOTAL	1.27	0.66	0.83	0.89	1.00

Source: Data compiled by Science-Metrix from Thomson-Scientific data prepared by OST. *Baseline: World = 1.00

Table 8a: Characteristics of knowledge intensive patents: Negative binomial model results

	Chinese Patents						**Indian patents**					
	Coef.	Std. Err.		Coef.	Robust Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Foreign Ownership	0.06	0.03	*	0.17	0.03	***	0.05	0.03	*	0.07	0.03	***
First Inventor (CN or IN)	-0.80	0.02	***	-0.45	0.02	***	-0.69	0.02	***	-0.57	0.02	***
1986-1995	0.58	0.06	***	0.48	0.05	***	1.33	0.08	***	0.98	0.07	***
1996-2006	1.06	0.06	***	0.99	0.05	***	1.87	0.08	***	1.56	0.07	***
Computers	-0.12	0.04	***	-0.11	0.04	***	-0.19	0.03	***	-0.10	0.03	***
Drugs	0.31	0.03	***	0.13	0.02	***	0.68	0.02	***	0.51	0.02	***
Electrical	-1.47	0.04	***	-0.80	0.04	***	-0.92	0.06	***	-0.52	0.05	***
Mechanical	-1.75	0.06	***	-1.24	0.05	***	-0.96	0.06	***	-0.59	0.05	***
Other	-0.72	0.05	***	-0.22	0.05	***	-0.96	0.08	***	-0.74	0.06	***
Biology				0.38	0.07	***				0.02	0.06	
Biomedical Research				0.28	0.02	***				0.20	0.03	***
Chemistry				0.05	0.03	*				0.00	0.03	
Clinical Medicine				0.24	0.02	***				0.17	0.03	***
Earth & Space				0.38	0.12	***				0.23	0.39	
Engineering & Tech				-0.03	0.05					-0.11	0.05	**
Health Sciences				-0.09	0.34					-0.93	0.55	*
Humanities/Social science				-0.62	0.29	**				-0.56	0.02	***
Mathematics				0.01	0.27					0.03	0.17	
Physics				0.06	0.04					-0.07	0.06	
Professional Fields				-0.75	0.11	***				0.01	0.28	
Psychology				0.45	0.07	***						
Constant	2.63	0.07	***	2.50	0.06	***	1.69	0.09	***	2.00	0.08	***
ln alpha	0.46	0.01		-0.28	0.01		0.22	0.01		-0.15	0.01	
alpha	1.58	0.02	***	0.76	0.01	***	1.25	0.01		0.86	0.01	
Log psuedo likelihood	-52654.2			-46323			-68486.99			-64103.39		
N	13469			10756			16026			14426		

Note: Omitted dummy is Chemicals for technology class, Period 1973-85, and Unassigned citations for Scientific field. Robust standard errors are reported.

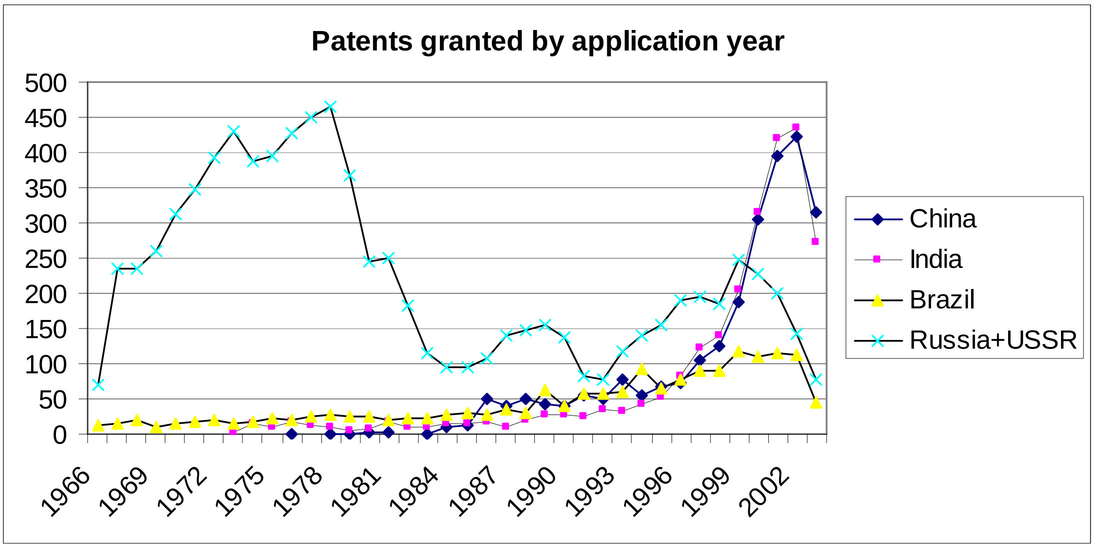
Table 8b: Characteristics of knowledge intensive patents: Poisson model results

	Chinese Patents						**Indian patents**					
	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Foreign Ownership	0.19	0.03	***	0.20	0.03	***	0.18	0.03	***	0.18	0.03	***
First Inventor (CN or IN)	-0.64	0.02	***	-0.47	0.02	***	-0.52	0.02	***	-0.44	0.02	***
1986-1995	0.40	0.05	***	0.41	0.05	***	1.29	0.08	***	1.03	0.07	***
1996-2006	0.96	0.04	***	0.94	0.05	***	1.99	0.07	***	1.73	0.07	***
Computers	-0.25	0.04	***	-0.12	0.04	***	-0.03	0.03		0.04	0.03	
Drugs	0.30	0.02	***	0.16	0.02	***	0.73	0.02	***	0.61	0.02	***
Electrical	-1.38	0.04	***	-0.71	0.03	***	-0.93	0.06	***	-0.51	0.05	***
Mechanical	-1.70	0.05	***	-1.21	0.04	***	-0.81	0.06	***	-0.47	0.05	***
Other	-0.55	0.05	***	-0.12	0.05	***	-0.99	0.07	***	-0.71	0.06	***
Biology				0.31	0.07	***				-0.17	0.05	***
Biomedical Research				0.27	0.02	***				0.11	0.03	***
Chemistry				0.06	0.03	*				0.08	0.03	***
Clinical Medicine				0.23	0.02	***				0.13	0.03	***
Earth & Space				0.39	0.10	***				0.53	0.38	
Engineering & Tech				-0.08	0.05					-0.17	0.05	***
Health Sciences				-0.18	0.36					-0.99	0.49	
Humanities/Social science				-0.54	0.25	**				-0.04	0.17	
Mathematics				0.09	0.25					-0.16	0.06	***
Physics				-0.10	0.04	***				0.00	0.28	
Professional Fields				-0.73	0.11	***				-0.75	0.02	***
Psychology				0.46	0.07	***						
Constant	-5.04	0.06	***	-5.08	0.06	***	-6.25	0.08	***	-5.96	0.08	***
Log psuedo likelihood	-176737.03			-136769.08			-264414.22			-233318.92		
Pseudo R2	0.29			0.21			0.24			0.20		
N	13469			10756			16026			14426		

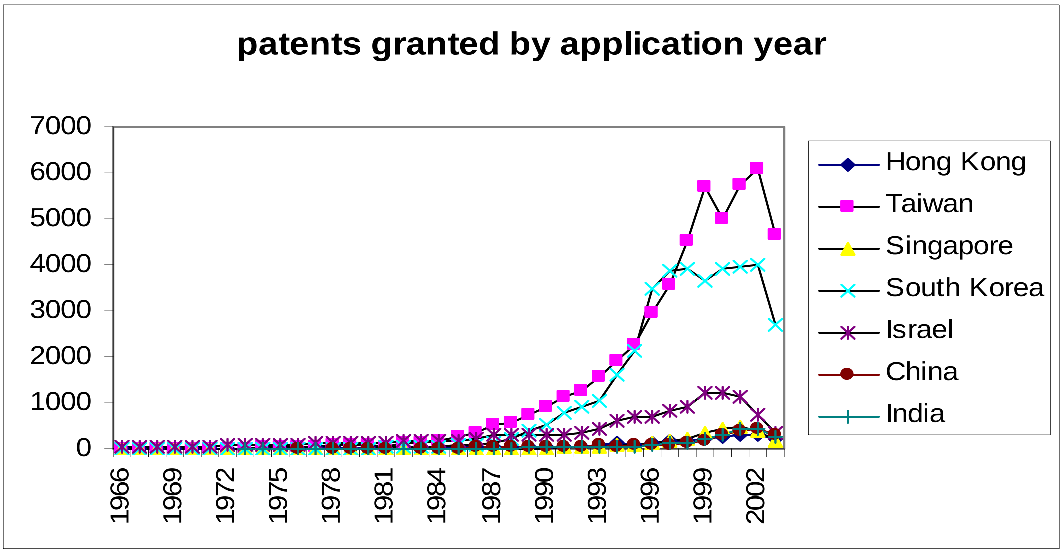
Note: Omitted dummy is Chemicals for technology class, Period 1973-85, and Unassigned citations for Scientific field. Robust standard errors are reported.

Figure 1 Patents granted by application year 1966-2003

a) India, China, Brazil, Russia&USSR



b) Comparison with Asian Tigers and Israel



c) Comparison with G7

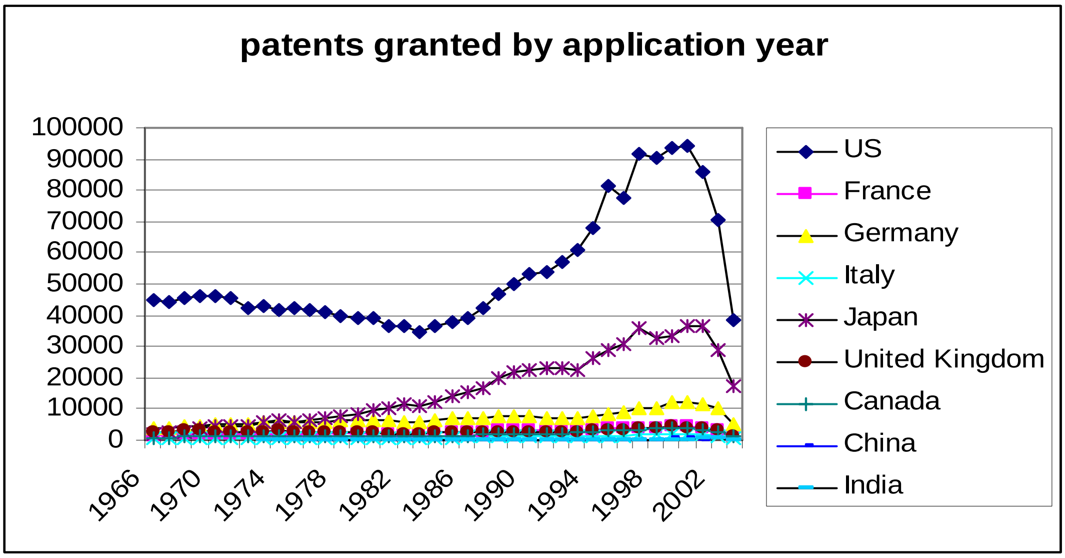
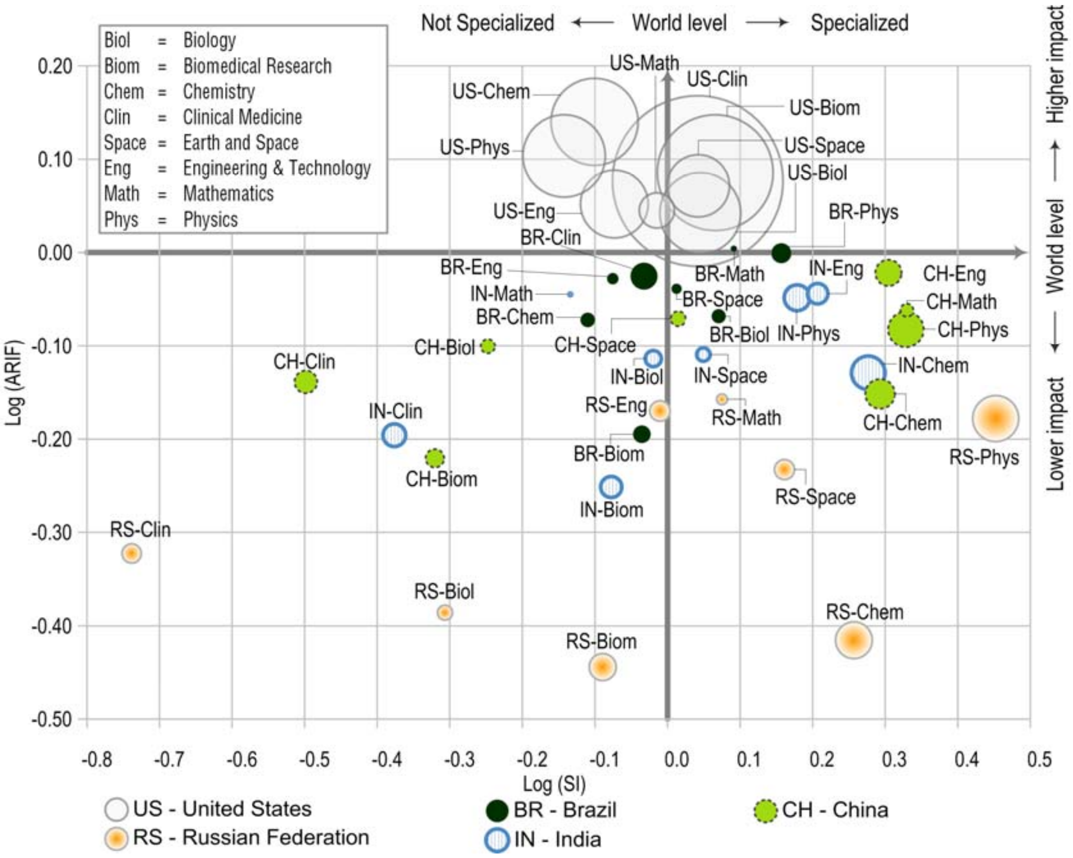


Figure 2: Positional analysis of selected countries in using the specialization index (SI), the average of relative impact factors (ARIF) and the number of papers (size of circles), 1990-2004



Appendix Table 1: Comparison of first inventor and any inventor datasets, China and India

Year of issue	USPTO 1st inventor CN	USPTO 1st inventor IN	Our database 1st inventor CN	Our database 1st inventor IN	Our database Any inventor CN	Our database Any inventor IN
1974						2
1975					0	3
1976				18	0	23
1977	1	14		13	0	18
1978	0	14		15	0	18
1979	1	14	2	16	2	21
1980	1	4	1	5	1	8
1981	3	6	3	9	3	13
1982	0	4		5		14
1983	1	14	1	17	3	20
1984	6	12	2	11	6	14
1985	1	11	1	11	2	14
1986	11	18	9	18	12	23
1987	23	12	21	12	30	20
1988	48	14	47	14	54	21
1989	52	15	52	14	59	18
1990	48	23	47	23	56	35
1991	52	24	51	23	63	32
1992	41	24	44	26	57	44
1993	53	30	55	31	70	41
1994	48	28	52	25	65	40
1995	63	38	69	37	89	63
1996	48	37	49	36	76	60
1997	66	48	67	47	95	72
1998	88	94	87	87	111	122
1999	99	114	97	111	156	153
2000	163	131	140	130	199	184
2001	265	180	226	178	300	231
2002	390	267	324	260	414	335
2003	424	355	355	346	452	433
Total	**1996**	**1545**	**1802**	**1538**	**2378**	**2094**
2004			472	364	600	449
2005			509	387	685	501
2006			304	228	419	315
Total			**3091**	**2518**	**4083**	**3361**