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Learning, Leaving and Linking: tapping the training, careers and networks of knowledge workers for developing countries

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INTRODUCTION

The concern of 'brain drain' from developing countries has been a pervasive focus in development studies for many years (Tanner, 2005, Zweig 2007). Thirty years ago, the US House of Representatives tabled a detailed report on the impact of the brain drain on the place of science and technology in American international relations (U.S. House of Representatives 1977). Their report showed that between 1962 and 1966 more than 45% of engineers and natural scientists accepted by the US as immigrants were from India and China.

Since the mid-1970s, however, the world of scientific training and careers has changed dramatically. By the late 1970s, however, a downward trend in the inflow of scientists and engineers to the United States was evident (U.S. House of Representatives 1977: 1279).In the Asian region, China's move from a centrally-controlled to a market-driven economy led to the formulation and implementation of new science and technology policies through the 1980s (Harvie and Turpin 1997). The resulting growth of research and training institutions and their contribution to industrial production through the 1980s and 1990s was dramatic (Zhang 2007). This was largely due to reforms that encouraged the mobility of scientists between the public sector and rapidly growing township village enterprises (Turpin and Garrett-Jones 1996)

In recent years India has emerged as a global leader in the IT and software sectors and as a major international player in the production and design of pharmaceuticals (Krishna 2007). Both China and India are now attracting significant global investments in R&D from the world's largest corporations. A recent study (Doz et al.) has shown that, over the next decade, the world's large business R&D spenders plan to place 75% of new R&D investments in these two rapidly expanding economies. Already many transnational corporations are planning to move to India and/or recruit scientific personnel from India.

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Cisco Systems has decided that 20 per cent of its top talent should be in India by 2012 and IBM's Vice President refers to India and China as the world's '…two biggest pools of high-value skills, which we want to leverage' (quoted in Giridharadas 2007).

Developed and developing nations alike, even more than before, seek to encourage the production and recruitment of highly skilled scientific and technical human capital (STHC) as a vital element of national innovation policies and of economic growth and social development (Bozeman et al. 2001; David & Foray 2002; OECD 1997, 2002). The value of scientific 'knowledge workers' for economic growth and competitiveness has grown as western economic systems have become more reliant on the knowledge-generating and value-adding capabilities of science and technology (Kleinman & Vallas 2001: 451; Stehr & Meja 2001). Tanner, commenting on the brain drain from Africa , has noted that in the US alone the Nigerian diaspora has enough doctors, lawyers, professors, scientists, administrators and business managers to run a first classw 21st century African economy (2005:91). The recently recognised importance of STHC and technology transfers in economic expansion has made competition for STHC resources a crucial element of strategy at firm, regional and national levels and led countries to seek to attract researchers to return 'home' ((Turpin et al. 2002; Laudel 2005).

The shift of science investments and indeed the flow of science and technology human capital (STHC) represents an important shift in science and technological capacity for the countries of the south. How are these developments in the huge and rapidly developing economies of China and India affecting STHC in other developing countries? Is there increased south/south scientific collaboration, through research training, networks and collaboration? Recent evidence has shown that through the 1990s there was minimal limited collaboration between Indian and Chinese scientists (Fuzhou paper). However, more recently this is changing. Abrol and Rupal, for example have documented the increased range of bilateral arrangements in selected fields. (Abrol and Rupa, 2008). In 2002 ,the two countries signed an MoU on S&T, space cooperation and hydrological data sharing. The Indian Space Research Organisation (ISRO) and the Chinese National Space Administration also signed a MOU on cooperation in the peaceful uses of outer space. In 2006, agreement was reached to launch joint research projects into earthquake engineering, climate change and weather forecasting, and nanotechnology and biotechnology (to focus on bio-nano research. The Indian Institute of Genomics and Integrative Biology and the Beijing Genomics Institute have entered an MOU for scientific collaboration in genomics and genome informatics. (Purnima Rupal and Dinesh Abrol, 2008).

The growth and success of some Asian countries are at least partly linked to the virtuous circle created by the interaction of public investment and private career choices. The dynamics of the migration of scientific and technological personnel are such that people in high demand seek out places which will provide them with good equipment, adequate research funding and a stable place of work or eventually enable them to go 'home'. These prerequisites are much easier to obtain in certain countries than in others. Whether we are seeing a 'brain drain' of the older type in new circumstances or whether the importance of open innovation in the competitive strategies of firms is such that they are willing to seek out and access information wherever it is held, contributing thereby to brain circulation rather than a drain, is not yet clear. At present, moreover, public investment in the region in the development of science and technology is aimed at local winning from a strong position and there are few specific public policies in the region which try to ensure that scientists can stay at home' and still do leading edge science and participate if they wish in the commercialisation of new knowledge. Encouraging brain circulation rather than gain and drain may need further intervention at an international level.

The present paper, based on a survey analysis of 10,000 scientists and their collaborators explores research mobility and collaboration between developing countries and between developing countries and the north. We focus in particular on research training, research networks, collaboratve arrangements and options for future move. Our finding is that India and China are indeed becoming important anchors for south south development. However, are findings also show that the countries of the north are still key anchor points. While we concur that a spoke and hub model for development in the south, as proposed by Osma (2008) Our warning is that the hubs must remain connected to the north for some time yet. Finally, we argue that while it is important to build scientific capacity at home (see for exampleHassan, 2008) policy options should pursue a dual strategy of promoting international mobility and building a community of science at home.

SOUTH-SOUTH RESEARCH COLLABORATION: AN OUTCOMES PERSPECTIVE

As background for this paper we have analysed the patterns of co-authorship between China, India, Mexico and Brazil. If the strategic bilateral science agreements between India and China are steering greater levels of collaboration between the two nations this should be reflected in an increase in co-authored publications. It was possible to extract publications data according to the authors' country of institutional affiliation. We interrogated the data held in the ISI web of science for the years 2001 – 2007.

The number of scientific publications by Chinese and Indian authors has risen dramatically over the past few years. For China the number has nearly trebled, for India and Brazil, the number has nearly doubled (see Table 1). Table 1 also shows some selected country co-authors. Because the Chinese output has grown so significantly the percentage increase in co-authorship is somewhat disguised. However, it is interesting to note that for China, the percentage of co-authorship with Indian and Mexican scientists has been maintained over the past six years. For India, the proportion of Chinese and Mexican co-authorship has risen. For Brazil the percentage of co-authorship with China, India and Mexico has remained fairly constant. For all three countries there has been a relative decline in co-authorship with the US and Japan.

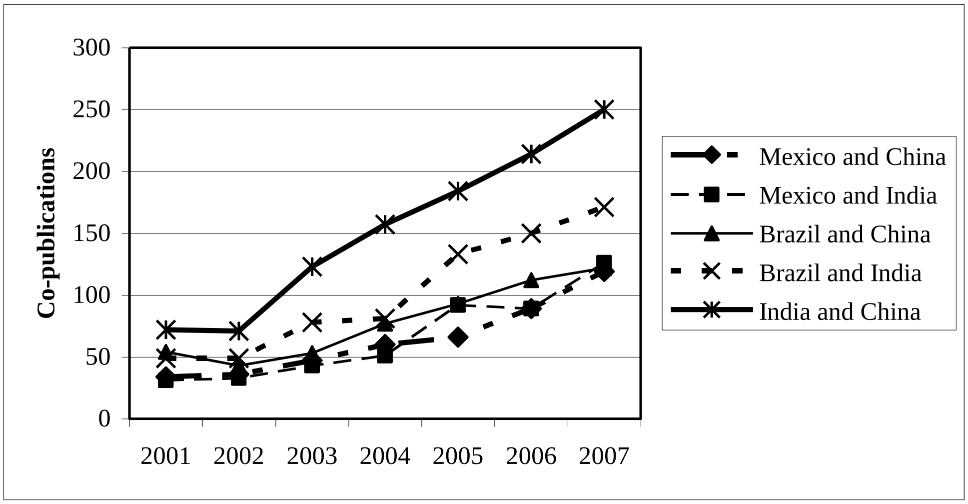
More interestingly, in terms of building networks, we have explored the actual number of collaborations between four countries: Brazil; China; India; and Mexico. For the process of network building we view the actual number of collaborations as being the critical factor, irrespective of the growth of national publications overall. The data presented in Figure 1 shows a significant rise in the actual number of co publications across the Pacific between Asia and the Americas, but particularly between India and China. Figure 2 shows the even sharper rise (albeit from a low base) for three-way co-authorships.

Table 1: Selected co-author countries: Brazil, China and India (001-2007)

	Year						
Co-author country	2001	2002	2003	2004	2005	2006	2007
			Brazilian authors (% all publications)				
Total pubs.	*11,034*	*12,388*	*13,681*	*14,350*	*16,757*	*18,306*	*18392*
China	0.71%	0.61%	0.79%	0.75%	0.86%	0.70%	0.65%
India	0.57%	0.52%	0.58%	0.61%	0.79%	0.68%	0.77%
Mexico	1.01%	0.77%	0.58%	0.74%	0.90%	0.80%	0.92%
US	13.03%	11.75%	12.26%	12.31%	11.37%	10.99%	11.76%
Japan	1.30%	1.27%	1.26%	1.31%	1.21%	1.23%	1.03%
			Chinese authors (% all publications)				
	2001	2002	2003	2004	2005	2006	2007
Total pubs.	*33,031*	*38,193*	*46,568*	*53,299*	*71,590*	*80,873*	*87,204*
Brazil	0.24%	0.20%	0.23%	0.20%	0.20%	0.16%	0.14%
India	0.37%	0.39%	0.35%	0.39%	0.43%	0.33%	0.36%
Mexico	0.13%	0.15%	0.11%	0.10%	0.11%	0.11%	0.12%
US	8.62%	8.32%	8.49%	8.23%	8.07%	8.14%	8.39%
Japan	4.23%	4.02%	4%	3.78%	3.36%	3.11%	2.90%
			Indian authors (% all publications)				
	2001	2002	2003	2004	2005	2006	2007
Total pubs.	*17,552*	*18,473*	*20,736*	*20,787*	*24,978*	*26,640*	*28,282*
China	0.70%	0.81%	0.79%	0.99%	1.23%	1.01%	1.10%
Brazil	0.36%	0.35%	0.38%	0.42%	0.53%	0.47%	0.50%
Mexico	0.20%	0.24%	0.16%	0.25%	0.31%	0.28%	0.36%
US	6.96%	6.59%	6.82%	6.69%	6.81%	6.83%	6.42%
Japan	1.93%	2.20%	2.31%	2.17%	2.34%	2.31%	1.92%

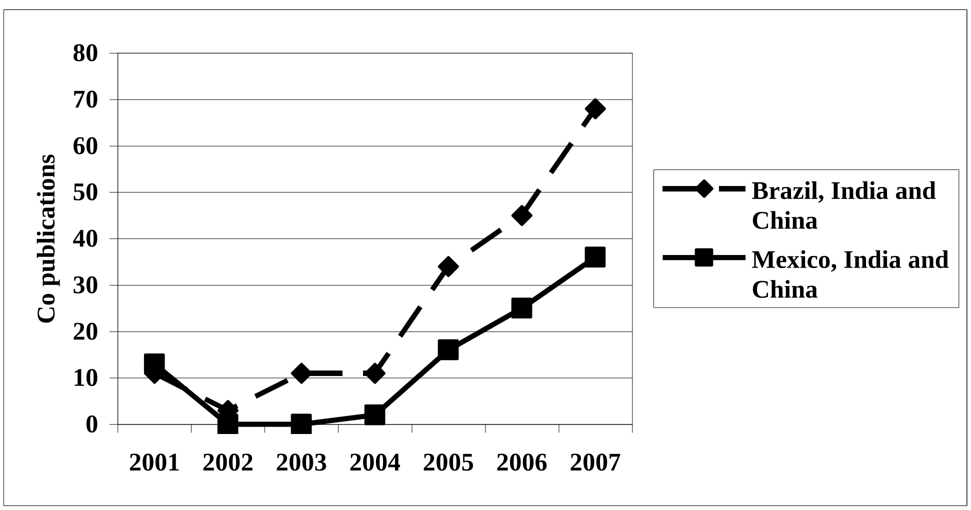
Source: ISI web f science

Figure 1: Co-authorship of scientific publications 2001- 2007



Source: ISI web f science

Figure 2: Three way co-authorship of scientific publications



Source: ISI web f science.

These data indicate some interesting outcomes. They clearly document transnational research collaboration as evident in co-authorship of scientific publications. Other analysts have drawn attention to increased international scientific collaboration between the US and developing economies. In particular, Osama (2008) has noted the rapid increase in collaboration between US and Indian scientists. He has proposed that while advances in communication have made collaboration easier there is an emerging scientific hierarchy of leaders and followers within developing economies. Based on a preliminary analysis of scientific publications we hypothesise that China, India, Brazil and Mexico are already emerging as leaders in the development of south focused regional knowledge hubs..

The data presented in Figure 2 illustrate the emerging role both China and India are playing in international south-south collaboration. These data show the rapid growth of three way collaboration involving these four countries. Starting from a very low base in 2001 with almost no three way collaboration there has been a steady increase through to 2007. Analysis of 2008 data suggest the trend is continuing. Collaboration, however, has not grown equally across all fields of science with the major growth areas in physics, mathematics, biology and medicine.

These trends have important implications for the smaller developing economies. Should they seek to maintain links directly with the scientific leaders in the north or should they seek to build links with these new and emerging knowledge hubs? And, if so, how do such networks emerge?

In the following section we present the results of survey data that seeks to map the formation of networks and collaboration. The results suggest there is a consistent pathway through which patterns of international collaboration are forged.

BUILDING NETWORKS FOR COLLABORATION: A SURVEY METHODOLOGY

The survey methodology that underpins this section was exploratory and based on a convenience sample drawn from the Science Citation Index (SCI) database (which excludes the social sciences and humanities). Author, institutional and email addresses of all papers for 2004 with at least one author from 22 Asia-Pacific locations were downloaded. This information was collated according to the country of lead author. The number of addresses collected for each of the 22 locations was approximately proportionate to the numbers of papers from these locations published in SCI journals in 2004.

An email inviting authors to participate in the survey was sent out which contained a link to a project and survey information page, along with an individual identification number and password to access the survey. The information page was available in English, Chinese, Japanese and Korean; the survey, however, was only available in English. The number of emails actual delivered was estimated at 50,000. A large number of emails bounced when sent (n≅20,000). The total number of useable responses received was 10,132.

Approximately four-fifths of respondents were from the researcher defined Asia-Pacific region. The leading co-author nationalities outside the region were the USA and the UK. Respondents were predominantly male (85.5%), with varying participation of female respondents observable for the different nationalities. Particularly strong female participation among respondents was evident from Thailand and the Philippines.

Table 2 shows the number of responses by gender for the 22 locations that defined the region on which the study sample was based. Table 2 also shows the number and gender of co-author respondents who were from outside the defined region. These 'other' nationalities also provide a guide to patterns of international research collaboration. Notably the countries with most co-authors collaborating with Asian scientists were: the US, UK, Germany, Canada, France and the Russian Federation.

For the present analysis country sub-group respondents were allocated, according to nationality, to six country/regional groupings. China (1) and India (2), because of their size, were kept as two separate countries. South East Asia (3) comprised respondents from Laos, Cambodia, Indonesia, Malaysia, Philippines, Thailand, Vietnam (n = 457); South Asia developing countries (4) included Bangladesh, Pakistan and Sri Lanka (n = 178); other developing countries (5) included mainly Asian but also including respondents from the Central and South America and Africa (n=245) and the North (6) which included mainly, US, UK, Germany, France, Canada, Russian Federation, Korea, Japan, Australia and New Zealand (n = 4700). It is important to note that that the first four sub-groups in the present sample were specifically targeted for the sample. The other two groups were in the sample because they were already collaborating as co-authors with Asian colleagues. Thus the sixth group, the countries of the North, represent a sample of scientists from those countries, that are *already Asia networked*.

In the following section we discuss the career mobility of these six groups. Our analysis draws on six variables: location of research degree, location of post doctoral employment, location of main research networks, location of most important research collaboration; and country of preferred future move (if intended). Two additional variables deal with respondents' experience of the quality of their research training and the reasons for preferred future move.

Table 2: Survey Respondents' Nationality and Gender

	Nationality	Male	Female	Total	% Total
Asia-Pacific locations	Australia	795	239	1034	10.21%
	Bangladesh	68	3	71	0.70%
	PR China	1449	193	1642	16.21%
	Hong Kong	44	6	50	0.49%
	India	1435	226	1661	16.39%
	Indonesia	30	9	39	0.38%
	Japan	1241	69	1310	12.93%
	Korea	689	47	736	7.26%
	Malaysia	110	46	156	1.54%
	New Zealand	240	74	314	3.10%
	Pakistan	82	16	98	0.97%
	Papua New Guinea	4	0	4	0.04%
	Philippines	29	26	55	0.54%
	Singapore	96	19	115	1.14%
	Sri Lanka	33	10	43	0.42%
	Taiwan	371	58	429	4.23%
	Thailand	121	96	217	2.14%
	Tonga	0	1	1	0.01%
	Vietnam	27	6	33	0.33%
Total Asia Pacific		**6864**	**1144**	**8008**	**79.04%**
Major co-author locations	Austria	19	5	24	0.24%
	Belgium	31	3	34	0.34%
	Brazil	21	1	22	0.22%
	Canada	105	20	125	1.23%
	Denmark	22	2	24	0.24%
	France	104	21	125	1.23%
	Germany	179	16	195	1.92%
	Iran	22	1	23	0.23%
	Italy	61	10	71	0.70%
	Korea (PR)	28	7	35	0.35%
	Netherlands	54	9	63	0.62%
	Poland	18	5	23	0.23%
	Russian Federation	70	2	72	0.71%
	Spain	26	10	36	0.36%
	Sweden	31	6	37	0.37%
	UK	202	44	246	2.43%
	USA	442	81	523	5.16%
Total co-author locations		**1435**	**243**	**1678**	**16.56%**
Others		**362**	**84**	**446**	**4.40%**
Total		**8661**	**1471**	**10132**	**100.00%**

Source: Scientists Survey, 2006.

LEARNING AND LINKING

A major first step toward a research career is the completion of a research degree. The majority of scientists in our sample completed this at home, however, a substantial proportion (around 30%) completed their research degree in another country. Scientific research training is a particularly important mechanism of tacit/embodied knowledge transfer. Much of the knowledge that is embodied as practical know-how, can be communicated across time and space, but there are aspects of knowledge transfer in scientific labour that are best achieved through collocated collective activity: in particular the formation of networks comprising colleagues and peers (Coe and Bunnell,2003). The network itself constitutes a capability in specific locations, a sort of academic capital that can be drawn down and shared over time and in different locations(see also Callon 1995). In other words, localised innovative capability can be enhanced by the intellectual, material and practical capacities that can be brought to bear by the network). Seen from this perspective international research training and the take up of early career post-doc research positions can be seen as also integral to the building of internationally dispersed knowledge networks (DKNs) (see Turpin et al 2008).

Research training

Table 3 shows the proportion of respondents from each sub-sample and whether they completed their research degree at home, in the south, or the north. Indians were the most likely to carry out their research training at home with only 14% travelling to another country for this purpose. For the Chinese 30% travelled to an international location for research training. For both groups this was mostly to countries of the north. For ‘Southeast’ and ‘Southern Asia’ and ‘other developing countries’ around 70% travelled off-shore to complete their research degree. The non-Asian group were more likely than the other groups to engage with research training in a country of the south. This is probably because of more limited opportunities and resources. For ‘the north’, their research training was almost entirely in the north.

Post doctoral studies

The second segment of Table 3 shows the location of post doctoral studies. A significantly larger proportion of those employed in post doctoral positions worked internationally. The Indian group, largely staying at home for research training were mainly engaged in post doctoral studies in the north. Compared to the Chinese their international networking was delayed, until this later stage in their carers. The South-east, Southern Asians and other developing country respondents were very much dependent on the north. In contrast both China and India had over 30% of their respondents engaged in post-doctoral positions at home. This figure was comparable with the group from the northern countries. Respondents from the north were almost entirely concentrated at home or in other northern countries for post-doctoral studies.

Research Networks and Research Collaboration

The third segment of Table 3 shows the location of what respondents' described as the country of their main research networks. These data show a similar pattern to the research training and post doctoral research experiences. For each sub-group the locations of training and post doctoral research appear to have been formative in developing networks. Further, as shown in the fourth segment of Table 3 these networks appear to be subsequently drawn-down into collaborative research activity, or alternatively convert to enduring research networks.

An interesting aspect of the north sub-sample is the extent to which they are focused on the south. There are a number of possible explanations for this. On the one hand it may suggest an interest among this group of scientists from the north in engaging with more applied research in the south. On the other hand the data may be reflecting the experiences of foreign born nationals who have since migrated to the north but continuing to work with scientists in their home countries.

Future Moves

In order to assess the likely mobility trajectories we asked respondents who were intending to make a geographic move in the near future the country of their preferred move. The results again follow a similar pattern to the results that emerged from the other variables. In addition we asked respondents why they intended to move. Table 4 shows the region of preferred move for each sub-group. The pattern reflects the pattern evident for networks and collaboration, but even more intensely. The focus of the north again shows a keen interest in the south, probably also for the same reasons proposed above for networks and collaboration. Overwhelmingly, all groups indicated that the reasons they wanted to move was to be 'closer to scientists working in their area of specialisation' or to be 'part of a scientific community or intellectual climate' (around 40%). This was similar for all of the sub-groups. Only % of respondents noted the opportunity for increased salary or broader social reasons, such as family migration ( ) for seeking to move. Only % cited better opportunities to engage with commercialising their research output. We conclude from this that these scientists' decisions to move location are very much driven by the desire to be part of a vibrant scientific community that is adequately resourced for research.

TABLE 2:
Country/Region of Nationality by Location of Research Training, Networks, Collaboration and Future Move

	Research Degree (%)				Post doctoral location (%)				Networks (%)				Most Imp. Collaboration (%)			
Region	n =	Home	South	North	n =	Home	South	North	n =	Home	South	North	n =	Home	South	North
China	1870	70	4.9	25.1	807	36.9	6.9	56.1	1735	32	6.7	61.3	1681	13.9	9.8	76.4
India	1478	85.9	1.3	12.9	763	31.5	2.9	65.7	1309	31.8	5	63.3	1192	16.9	6.5	76.6
South-east Asia	457	30.2	2.6	67.2	142	10.6	5.6	83.8	428	11.9	5.6	82.5	422	6.9	5.7	87.4
Other South Asia Developing	178	34.3	8.4	57.3	72	5.6	6.9	87.5	164	24.4	9.1	66.5	154	7.8	9.1	83.1
Other Developing Countries	245	31.4	17.6	51	130	12.3	11.5	76.2	237	7.6	18.6	73.8	237	1.3	16.9	81.9
The North	4700	77.4	2.5	20.1	2527	38.8	3.1	58.1	4544	25	9.4	65.6	4422	9.4	13.5	77.1
All	8928	72.7	3.3	23	4441	35.0	4.1	60.9	8417	26.3	8.2	65.5	8108	11	11.3	77.7

Source: Scientists Survey 2006

Table 4: Region of Preferred Future Move

Region	Future Move (%)		
	n =	South	North
China	716	12.3	87.7
India	734	6.1	93.9
South-east Asia	143	7.7	92.3
Other South Asia Developing	106	8.5	91.5
Other Developing Countries	89	16.9	83.1
The North	916	15.2	84.8
All	2704	11.4	88.6

DISCUSSION

The data presented above for patterns of co-publication and our survey data on scientist mobility show a growing significance of the scientific home base for China and India Growing R&D investments in India and China, particularly in the increasingly sophisticated special economic zones are likely to also provide growing opportunities for careers. They will also provide a growing focus for collaboration through dispersed knowledge networks. As scientific engagement increases through post-doctoral studies and research sabbaticals, it is likely that scientific mobility and on-site collaboration in these areas will also increase. As international activities expand, they will offer new opportunities for both doctoral research and post-doctoral training. Sophisticated research infrastructure and the opportunities to collaborate with world class researchers are important factors pulling scientists to particular areas, including home countries in the region.

The movement of larger numbers of expatriates from specific countries into these dispersed networks bring a second dimension – the diaspora network. The effect of the latter can be to direct scientific discovery toward particular home based issues. The growth of the large economies of India and China makes it likely that some of the smaller and less developed countries in the Asian region will find it difficult to retain scientists within their own systems or to gain access to new knowledge and problem solving capabiligties.

However, the integration between dispersed knowledge networks and diaspora knowledge networks is in our view a new phenomenon. It is evident in the publications data introduced earlier in this paper and it is evident in our survey data. In this context international mobility does not necessarily mean that the ‘losing’ countries will have no benefit whatsoever from their investment in the scientific education of their young people. As Mahroun et al. (2006) have suggested, there is potential for developing countries to capture some benefit from their professionals abroad, beyond simply receiving remittances. Using the example of the health care professions, they suggest that sending and receiving countries could benefit by supporting links between senders and receivers in formalised development programmes. The general thrust of this position is compelling but may require special policy initiatives if maximum use is to be made of the opportunities. These initiatives may be taken by the countries concerned and/or by international aid agencies assisting the countries of the region.

Thus, for example, the data presented in this paper on scientists suggest at least one way forward. Post-doctoral studies offer important network building opportunities. The location in which post-doctoral training is received is formative both in terms of where scientists eventually work and where their long term networks reside. A study of post-doctoral fellowships awarded to Australian scientists in the early 1990s drew attention to the importance of these awards in steering future career options (Marceau and Preston 1997). Countries themselves, perhaps in collaboration with others, may be able to devise career structures which enable their best and brightest who may be tempted to remain overseas after finishing their training to return for regular periods and teach or undertake specific projects at ‘home’. Returning graduates of this kind bring with them much needed tacit knowledge about new scientific methods, equipment and promising areas of enquiry. Properly supported at home they can quickly make significant contribution. The study by Marceau and Preston showed, for example, how important this inflow of new information could be even in the context of Australian science. It also showed how in at least one institution senior professors had long term strategies for maximising both the chances of their graduates going to the best places in their fields overseas and returning home from overseas. These senior scientists then rapidly integrated the knowledge returnees brought with them into the work of the labs to which they returned.

As Hassan (2008) has argued, there does need to be a sustainable home science base for this to occur. Science careers in all smaller countries urgently need to be rethought so that access can be ensured to the best centres overseas without the home countries losing out; much science can be undertaken through access to equipment and centres of excellence for periods and then followed through elsewhere. This kind of approach makes returning much less of a ‘once and for all’ decision and introduces flexibility for the scientific and technological personnel concerned. ‘Being there’ is important. It is important for building links between smaller and less developed countries and those scientists more central to a regional knowledge hub.

International development efforts also could be usefully re-directed in similar ways. They could, for example, introduce post-doctoral awards for top young scientists to be taken up in *targeted* locations around the world. The location should vary according to the national scientific strength and research priorities of the various sending countries. The selections should be strategic, with the logic of building on existing or emerging strengths by locating specialists closer to the centre of regional knowledge hubs. Many policy makers may feel this is a risky option, one likely to further the loss of national talent from developing countries because it might potentially lead to a geographic ‘brain loss’. Our view is that this approach should be seen as complementary to other development strategies that seek to build local scientific infrastructure and research management capacity at home.

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